Human Diversity: design for life

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Preface

This year's biennial International Congress of Physiological Anthropology was hosted by the Technical University in Delft from 22-26 August 2008. The conference was small but beautiful with about 80 delegates from more than 11 countries. 16 keynote speakers and more than 40 oral and poster presenters showed their papers on a variety of topics related to the conference theme 'human diversity: design for life'.

After meeting you at the ICPA Conference in Delft, it is a great pleasure again to offer you the Congress book, showing a selection of the presented papers of this year's ICPA Conference.

I am sure you will enjoy browsing and reading trough the various contributions of this book and they will inspire you for your future work. You can show the book to others that were not at the conference and are curious about it. And fore sure, we hope you will remember the nice conference in Delft each time you see the book on the shelf!

Over the past 25 years Physiological Anthropology has focused on Human Adaptability to physical environments using laboratory methods, which controlled some physical factors. The adaptability was evaluated in terms of body temperature regulation, respiratory and cardiovascular functions and body composition, or physical fitness. The collected data has been applied to actual space as well as products in daily life through cooperation with business and companies.

One of the aims of Physiological Anthropology is "to conduct research into humans in modern society from both a physiological and a cultural standpoint, in an effort to create a truly healthy and comfortable living environment as rapid advances in Science and Technology are having a profound effect on the human community, in terms of not only lifestyle and culture but the physiological capabilities of the human body as well". (Japan Society of Physiological Anthropology).

We now started to pay attention to individual differences in these physiological parameters, which should be considered not as errors, but as natural variation between individuals. The designers in this world should take into account these variations between individuals because designing for the average does not make sense as the average man does not exist.

I would like to thank a few people that helped us to make this conference and this book: Prof Nick Mascie-Taylor, Hajime Harada, Akira Yasukouchi as my fellows in the Congress Committee. Many credits go to our reviewers, who donated a lot of time to carefully read and evaluate the submissions: Akira Yasukouchi, Tetsuo Katsuura, Nina Smolej Narancic, Hajime Harada, Koichi Iwanaga, Douglas Crews, Gerry Brush, Yoshifumi Miyazaki, Elena Godina and Lawrence Schell.

I also would like to thank the Faculty of Industrial Design Engineering, in particular the Dean Professor Dr Cees De Bont for sponsoring the Congress dinner and the department Facility Management for their support. And last but not least I would like to thank Tommy Louts and Miriam Reitenbach in the second phase and Sonja van Grinsven in the starting phase, who organised in fact the whole event and this book.

Yours sincerely,

Prof. Dr. Johan FM Molenbroek, Congress Chair

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DESIGN FOR LIVING

RESEARCH IN PHYSIOLOGICAL ANTHROPOLOGY AND DESIGN

Human Diversity

Nature versus nurture in the context of anthropometric variables

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ABSTRACT

Variation in height within populations is though to be due to controlled by a combination of genes (Nature) and the environment (Nurture). This paper reviews the contribution of Mendel to our understanding of genetics and goes on to describe the theory of heritability (the genetic component of the variation) as well as how heritability is quantified in humans. It discusses the latest genome-wide search for height genes and draws attention to the role of the environment in modifying phenotypes.

1. INTRODUCTION

The Nature versus Nurture debate refers to the relative importance of genetic factors (Nature - the extent of the genetic variation between individuals) and the environment (Nurture – variation in diet, disease, exercise and living conditions between individuals) in explaining the variation of a trait within a population (Cavalli-Sforza and Bodmer, 1971).

As far as height is concerned the first person to examine the genetics of height was Gregor Mendel – the father of modern human genetics. He examined the inheritance of height in peas, but his approach has relevance to our understanding of how genes operate. Mendel was an Austrian monk who experimented between 1856 and 1863. He published his results in 1866 but it was not until 1900 that his work was given the credit it deserved.

What Mendel was able to do was to breed Tall and Short pea plants which were 'true breeding' i.e. if a tall pea plant was crossed (mated) with a tall plant, all the daughter pea plants were also tall and indistinguishable from the parental stock. Likewise with the short plants (short X short parental plants produced only short daughter plants). Mendel had the advantage that he was dealing with a discrete trait whereby plants were either tall or short and did not show intermediate height.

Then he mated a tall true breeding plant with a short true breeding plant and found that all the daughter plants were tall, as tall as the parental stock. When he self-fertilised the daughter tall plants (so called FI generation) he found that the in the subsequent generation (F2), tall and short plants, were produced in a ration of 3:1.

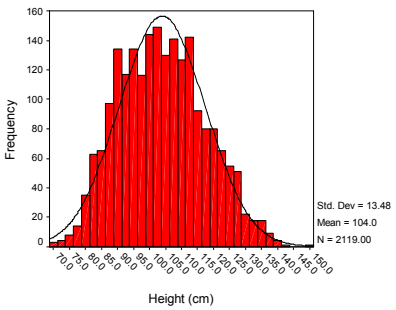

Figure 1: Height Distribution

He explained these results by suggesting that all true breeding tall plants had a genetic constitution (genotype) of TT and short of tt. When a Tall and Sort plant were mated only one of the two hereditary factors were passed on – so a Tall plant passed on a T hereditary factor (gene) and a short plant and t factor (gene). So all the offspring had a genotype of Tt. When he self-fertilised the F1 generation he reproduced the parental types (Table 1).

Table 1: Segregation of alleles

	T	t
T	TT Tall	Tt Tall
t	Tt Tall	Tt Short

3:1 ratio of Tall and Short

The problem with humans is that many of the characters of traits of interest do not show discontinuity as observed by Mendel – instead they show a continuum from very short to very tall people (Figure 1). So part of the variation is thought to be due to genetic differences between people and part due to the environment. The

underlying genetic variation for characters such as height and weight is thought to be due to the action of many genes (polygenes), inherited in the simple Mendelian way as demonstrated by Fisher in his classic 1918 paper, but each gene has a small effect, rather than the large major gene effects observed by Mendel in peas.

2. THEORY OF HERITABILITY

Simplistically, the total variation (VT) of a character can be portioned into two components, genetic (VG) and environmental (VE). So the total variation (VT) = VG + VE. The proportion of the total variation due to genetic factors is termed the heritability (h^2) .

So h^2 = Genetic Variation (VG) / Total variation (VT)

So the heritability is a population characteristic and can vary both temporally and spatially. Heritability has no meaning for an individual. The heritability is neither constant or immutable – if the genetic variance changes of the environmental conditions are modified, then the heritability can change.

If the h2 = 1, all the observed variation is due to genes, if h h^2 = 0, all the variation is environmental, if h^2 = 0.60, then 60% of the variation is due to genetic differences between people and 40% to the environment.

3. DETERMINATION OF HERITABILITY IN HUMANS

A number of methods exist for the determination of heritability in humans, including

1. parent-offspring association

2. sib-sib association

3. Twin reared together or apart

The parent-offspring association method assumes that a parent passes on half his or her genes to his/her offspring. So if the regression coefficient (b, slope of the line) of offspring stature (Y axis) against parental stature (X axis) was 0.35, then b = h^2 , so the heritability = 0.70. The problem with this method as well as the sib-sib association methods is that it assumes that all the likeness between parent and child is due to genes, which, of course, is incorrect, since they also usually also share a common familial environment. So heritability determined by parent-offspring and sib-sib methods will tend to elevate the genetic component by an unknown amount.

The method which is used most widely to determine the heritability is the Twin Method. Identical or monozygotic twins (MZ) develop from a single zygote which divides for into two fertilised eggs, with identical genotypes. Fraternal of dizygotic (DZ) twins develop from two separately fertilised eggs and have different genotypes, just like brothers and sisters.

Identical twins (MZ twins) are twice as genetically similar as fraternal twins (DZ twins) and so heritability is approximately twice the difference in the correlation between MZ and DZ twins, $h^2=2(r(MZ)-r(DZ))$.

Variable	MZ	DZ
Height	0.93	0.48
Weight	0.91	0.58

So the heritability of height is 2(0.93 – 0.48) = 0.90, and for weight 2(0.91-0.58) = 0.66.

The Twin Method has been criticised and it is important to note that twins are not a random sample of the population, and they differ in their developmental environment. In this sense they are not representative of the general population.

Occasionally identical twins have been separated soon after birth and brought up in separate homes. If they are truly separated, then it would seem that the only explanation of any resemblance between them must be their identical genotypes. A number of separated MZ (MZA) twin studies have been undertaken and one of the largest is that undertaken by Tom Bouchard and his colleagues (REF). One of the earliest twins studied by Bouchard (1984) were the Jim twins – identical twins Jim Lewis and Jim Springer from Ohio, USA, separated when 4 weeks old, each infant was taken in by a different adoptive family. But there were amazing similarities between the twins; as youngsters, each Jim had a dog named 'Toy', each Jim married twice – first wives both called Linda and second wives both called Betty, each twin drove the same model and colour of car to the same Florida beach for family vacations, both smoked the same Salem cigarettes and drank Miller Lite beer and both had been part-time sheriffs.

The relative importance of genes and the environment can illustrated in these two figure. In the upper one, MZA and MZT have a much higher correlation than DZT which signifies that genes are more important. In the lower figure DZT and MZA are close together signifying greater importance of the environment.

DZT		MZA	MZT
0.5			1.0
	Correlation		

DZT	MZA	MZT
0.5		1.0
	Correlation	

The first study of MZAs was undertaken by Newman, Freeman and Holzinger (1937). They studied both the intelligence and anthropometry of American separated adult identical twins and compared them with adult identical twins reared together as well as sibs. The results (Table 2) show that the correlations are much higher for MZA than DZT, indicating the greater importance of genes than the environment

Table 2 Anthropometric data on twins and sibs from Newman, Freeman and Holzinger

Difference (r in brackets)	MZT (n=50)	MZA (n=19)	DZT (n=50)	Sibs (n=52)
Height (cm)	1.7 (0.932)	1.8 (0.969)	4.4 (0.645)	4.5 (0.600)
Weight (kg)	1.9 (0.917)	4.5 (0.886)	4.6 (0.631)	4.7 (0.584)
Head length (mm)	2.9 (0.910)	2.2 (0.917)	6.2 (0.691)	-
Head width (mm)	2.8 (0.908)	2.9 (0.880)	4.2 (0.654)	-

In 1962, Shields published data on British twins and he also found that the MZA were more similar to MZT than to DZT.

Table 3 Anthropometric data on twins from Shields

Difference (r in brackets)	MZT (n=50)	MZA (n=19)	DZT (n=50)
Height (cm)	1.3 (0.96)	2.1 (0.82)	4.5 (0.44)
Weight (kg)	4.7 (0.80)	4.8 (0.62)	7.9

4. GENOME-WIDE ASSOCIATION STUDIES

Genome-wide association studies interrogate the entire genome for associations between common gene variants, single nucleotide polymorphisms (SNPs) and a phenotype. The initial research on 5000 people of European descent found an association between a gene called 'highly mobile group A2' or HMGA2 and height. People with two copies of the variant gene tended to be 1 cm taller than those with no copies of the variant gene, while those with one copy were 0.4 cm taller (Weedon et al, 2007). In May 2008, two groups reported on further advances with one group reporting on 20 loci (Weedon et al. 2008) that influence stature and the other group 10 loci (Lettre et al, 2008). However the two amount of height variation explained was only 3% with a 5 cm difference between the 6.2% of people with 17 or fewer 'tall' alleles compared with the 5.5% with 27 or more 'tall' alleles. A very recent review (Weedon and Frayling, 2008) suggested that there are now 44 loci which influence normal variation in height. So even a 'simple' trait, like height, heavily influenced by genes, is turning out to be controlled by several hundred genes, rather than a few all-powerful ones.

5. IMPACT OF THE ENVIRONMENT

Even for a trait with a strong genetic component the environment can bring about dramatic increases or decreases in mean values. Changes in cultural practices, improvements in diet and reductions in infectious disease can account for massive jumps in anthropometric variables over the course of one or two generation. In many countries the average stature has increased substantially over the last few generations and Dutch males are now, on average, 20 cm taller than 150 years ago (Cole, 2003). For example, Lebanese Maronites living in Lebanon showed hyperbrachycephaly – flat, wide heads, which was thought to be due to a rare genetic condition. But those who migrated to the USA showed a normal skull shape. The 'odd' skull shape in Lebanon was due to placing the infant in a wooden cradle for 18 hours a day – the soft malleable skull became flattened by the hard wooden surface. Lebanese Maronites who migrated to the USA ceased to use that cradling practice and hyperbrachycephaly and the flat-backed head disappeared (Ewing, 1950)

Figure 1: Hyperbrachycephaly in Lebanon and a Normal skull in USA.

Environmental plasticity can be shown from migration studies (see Mascie-Taylor and Little, 2004, for review), for example, Japanese migrants Hawaii were different from non-migrant (sedentes) relatives, and their offspring were even more different (Table 4), and were much more like native-born Hawaiians (Shapiro, 1939).

Table 4 Impact of Migration on Anthropometry

Male	Japanese Sedentes	Japanese Immigrants	Hawaiian Born Japanese
Stature (cm)	158.39	158.72	162.83
Head Length(mm)	189.70	189.38	186.54
Head Breadth(mm)	151.90	152.72	155.08
Cephalic Index	80.22	80.72	83.32

So it is not Nature versus Nurture but Nature and Nurture!

6. REFERENCES

Bouchard T J (1984). Twins reared together and apart: What they tell us about human diversity. In Individuality and determinism ed S W Fox pp 147-178. Plenum, New York.

Cavalli-Sforza, LL and Bodmer, WF (1971) The Genetics of Human Populations. W H Freeman and Company, san Francisco

Cole, TJ (2003). The secular trend in human physical growth: a biological view. Economics and Human Biology, 1, 161-168.

Ewing, JF (1950). Hyperbrachycephaly as influenced by cultural conditioning. Papers of the Peabody Museum of American Archaeology and Ethnology 23 (2).

Fisher, RA (1918) the correlation between relatives on the supposition of Mendelian inheritance. Transactions of the Royal Society of Edinburgh, 52, 399-433.

Lettre G, Jackson AU, Gieger C, Schumacher FR, Berndt SI, Sanna S, Eyheramendy S, Voight BF, Butler JL, Guiducci C, Illig T, Hackett R, Heid IM, Jacobs KB, Lyssenko V, Uda M; Diabetes Genetics Initiative; FUSION; KORA; Prostate, Lung Colorectal and Ovarian Cancer Screening Trial; Nurses' Health Study; SardiNIA, Boehnke M, Chanock SJ, Groop LC, Hu FB, Isomaa B, Kraft P, Peltonen L, Salomaa V, Schlessinger D, Hunter DJ, Hayes RB, Abecasis GR, Wichmann HE, Mohlke KL, Hirschhorn JN. (2008).

Identification of ten loci associated with height highlights new biological pathways in human growth, Nature Genetics, 40, 584-91.

Mascie-Taylor, CGN and Little, MA (2004). History of Migration Studies in Biological Anthropology, American journal of Human Biology, 16, 365-378.

Newman, HH, Freeman, FN and Holzinger KJ (1937) Twins: A Study of Heredity and Environment. University of Chicago Press, Chicago.

Shapiro, HL (1939). Migration and environment: a study of the physical characteristics of the Japanese immigrants to Hawaii and the effects of the environment on their descendants. Oxford University press, Oxford.

Sheilds, J (1962) . Monozygotic twins Brought up apart and brought up together. Oxford University Press, Oxford.

Weedon MN, Lettre G, Freathy RM, Lindgren CM, Voight BF, Perry JR, Elliott KS, Hackett R, Guiducci C, Shields B, Zeggini E, Lango H, Lyssenko V, Timpson NJ, Burtt NP, Rayner NW, Saxena R, Ardlie K, Tobias JH, Ness AR, Ring SM, Palmer CN, Morris AD, Peltonen L, Salomaa V; Diabetes Genetics Initiative; Wellcome Trust Case Control Consortium, Davey Smith G, Groop LC, Hattersley AT, McCarthy MI, Hirschhorn JN, Frayling TM. (2007) A common variant of HMGA2 is associated with adult and childhood height in the general population. Nature Genetics, 39, 1245-1250.

Weedon MN, Lango H, Lindgren CM, Wallace C, Evans DM, Mangino M, Freathy RM, Perry JR, Stevens S, Hall AS, Samani NJ, Shields B, Prokopenko I, Farrall M, Dominiczak A; Diabetes Genetics Initiative; Wellcome Trust Case Control Consortium, Johnson T, Bergmann S, Beckmann JS, Vollenweider P, Waterworth DM, Mooser V, Palmer CN, Morris AD, Ouwehand WH; Cambridge GEM Consortium, Zhao JH, Li S, Loos RJ, Barroso I, Deloukas P, Sandhu MS, Wheeler E, Soranzo N, Inouye M, Wareham NJ, Caulfield M, Munroe PB, Hattersley AT, McCarthy MI, Frayling TM (2008) Genome-wide association analysis identifies 20 loci that influence adult height, Nature Genetics, 40, 575-83.

Weedon, MN and Frayling, TM. Reaching new heights: insights into the genetics of human stature. Trends in Genetics, 24, 595- 603.

Physiological variation from the perspective of adaptability to artificial environment

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ABSTRACT

Physiological variation was conceptualized by the three keywords of physiological polytypism, functional potentiality, and whole body-coordination employed in the field of physiological anthropology, and examined how the variation was molded in a current society in view of the relationship between human behavior and adaptation to stresses from the environment. The subject of physiological polytypism is composed of whole-body coordination and functional potentiality, which is corresponding to apparent part and latent part, respectively. Degree of apparent part of functional resources in humans might depend on the acquired behavioral history. Human behavior in a highly technological environment based on emotion tends to depend on cultural medium for adaptation, which result in sedentary lifestyle and affecting biological adaptability to the environment, such as changes in BMR and cardiovascular response associated with cold and orthostatic tolerances, degrees of melatonin release and suppression at nighttime.

It was concluded that we need to consider the balance between human behavior based on emotion and highly technological environment to keep biological adaptability in good condition. In other words, we need to improve environmental design and to have some biological guideline for human behavior by cooperation with physiological anthropologist and environmental designer.

1. INTRODUCTION

There is a certain practical limitation in evaluating human adaptability to modern environments. Apart from inter-individual variation, physiological responses to the environment vary even within individuals due to biological rhythms, physical conditions, and other factors. While many accept the convenient and comfortable living environment without hesitation, adaptability of the human body may not be able to cope with and adequately adjust to the stressful environment thereof, thus molding inter-individual variations in the pattern of physiological responses in terms of different behavioral patterns and historically acquired lifestyle practices in a modern society. It is important to understand the relevant issues based on data accumulated in the field of physiological anthropology, and to suggest modifications of social practices deemed corrective and appropriate in constructing a living environment best suited for human resources. Therefore, we should always bear in mind that humans display multifaceted responses to different physical and cultural factors prevailing in the technologically comfortable environment in evaluating the responses as being valid or otherwise. Physiological variation was considered here in view of three keywords; physiological polytypism, functional potentiality, and whole body-coordination (Sato, 2005; Yasukouchi, 2005). In the present study, intra- and inter-individual variations were demonstrated in certain aspects related to historically acquired lifestyle practices and environmental condition. The results imply that these physiological variations should be taken into consideration to enhance designing the quality of products and/or artificial environments.

2. THEORETICAL PERSPECTIVE OF PHYSIOLOGICAL VARIATION AND HUMAN BEHAVIOR

Homeostasis is maintained in all organisms for survival against various stresses in the environment, and the process to successfully accommodate various stresses results in adaptation. Homeostasis is functionally realized through accommodation of the body systems, or as a result of coordinated functions of many elemental organs (whole-body coordination), which in fact is one of three keywords. The body system accommodates, changes and develops with a defined direction dependent on the behavioral history or on exposed to the type, magnitude, and frequency of stress, which as a whole molds the characteristic phenotype or polytypism. In a case of humans, the history of the stresses encountered in the life is selected by intended behavior.

The stress from the environment is reduced by adaptation. Fig. 1 shows the relationship between human behavior and adaptation to stresses from the environment. “Adaptation”, defined here as the means employed to buffer stress from the

environment, generally divided into "biological medium (buffers on the human side)" and "cultural medium (buffers on the side of environment)". Both these buffers mutually influence the human-environment relationships; viz., genotype and phenotype on the human side as well as hard media and soft media (rules) on the environment side should be taken into consideration. Hard medium is the all products primarily reducing physical stresses such as air conditioner, automobile, media products and so on, soft medium is rules mainly reducing mental stresses from social organization such as low, custom, tradition and so on.

The environment is considered as stressors here, the balance between natural environment and artificial environment including cultural medium have to be concerned.

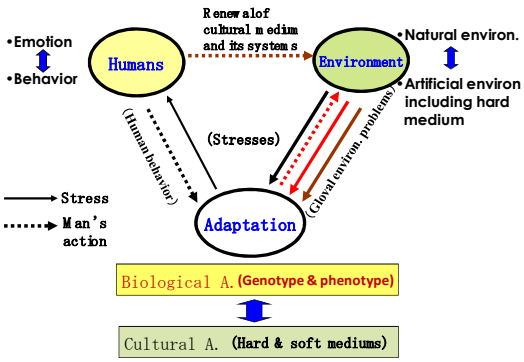

Figure 1: The relationship between human behavior and adaptation to stresses from the environment.

"Human" is positioned with the leading action, while "emotion" and "behavior" as the drive and output of the action, respectively. Emotion may be categorized as pleasantness and unpleasantness as a whole. Appropriation of adaptation methods to buffer stress from "environment" is determined based on emotion (broken arrow). When the cultural medium is exploited positively for adaptation, the results on "environment" then assume the form of much energy expenditure and waste as global environmental issues (broken arrows). Therefore, the more the dependence to the cultural medium is, the more the environmental stress will be generated per se, resulting in showering various influences on humans. Long-term persistence of this process may exert novel effects on the genotype and phenotype molding the biological adaptation medium. Selection of human behaviors in molding the adaptation methods elicits potent effects on the balance between biological adaptation and cultural adaptation; a relationship critical for evaluating the perspectives of physiological anthropology. Moreover, emotion of humans intended to modify the cultural medium for higher satisfaction and to renew the relevant systems alters the mechanism and structural framework of artificial environments one after another, thus initiating another form of stress. Note that technoadaptability under such circumstances will be verified accordingly.

Adaptability depends mainly on maximum tolerance to stress which is basically determined by genetic composition. Fig. 2 illustrates the relationship between human behavior or cultural adaptation and functional potentiality. There are two different phenotypes of intrinsic tolerance; resistance adaptation (the ability to resist extreme stress), and capacity adaptation, which is the efficiency or effect of physiological response to trivial stress usually experienced in our daily-life activity (Precht H, 1958).

Tolerance levels change according to behavioral history; viz., the tolerance level is dependent on the incidence of severity and/or frequency of stress encountered in our time-related environments (see Fig. 2). The tolerance level decreases with increases in the latent degree of functional ability and/or efficiency on exposure to chronically trivial stress; i.e. the relationship between apparent and latent degree of functions resembles that of the inside-outside of the body system. Thus, the apparent part of function depends on human behavioral history or cultural adaptation.

As is increasing dependency on cultural adaptation, the stress encountered in a daily life is getting small, which means that the latent degree of functional tolerance becomes large.

This latent degree surely affects functional body system, or whole body-coordination, to maintain homeostasis. Thus, dependency on cultural adaptation or human behavioral history, affects biological adaptability to the environment, which possibly forms characteristic phenotype of physiological function, or coordinated responses to the environment.

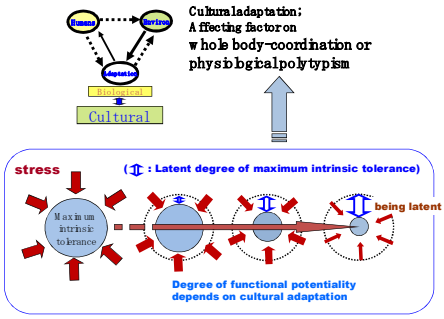

Figure 2: The relationship between human behavior or cultural adaptation and functional potentiality.

We have to consider biologically appropriate environmental condition, that is, design for life in view of human adaptability to the modern environment.

3. PHYSIOLOGICAL POLYTYPISM IN A CURRENT ENVIRONMENT IN JAPAN

We should always consider that humans display multifaceted responses to different physical and cultural factors prevailing in the technologically comfortable environment and thus we should evaluate and judge the responses as being valid or otherwise.

Various perspectives have to be taken into consideration in studies and in drawing conclusions: the biological significance of physiological polytypism has to be appropriately examined, and a certain adapted environment may have been underestimated, or polytypism may, on the contrary, may have molded unintended disadvantageous outcomes.

It should be examined whether a characteristic pattern of coordinated response, or physiological polytypism exists in a current environment.

3.1 Variation in BMR related to behavioral pattern

According to an investigation on the effects of daily behavior pattern or historically acquired lifestyle practices on basal metabolic rate (BMR) by Maeda et al. (2005), the BMR is reduced in a case where snack-eating between meals and in a case where daily physical activity is relatively lower**.** Further studies on the relationship between BMR and the source/preparation of nighttime meals (Maeda et al., 2005) have revealed that BMR significantly decreases in cases who take nighttime meals purchased at convenience stores compared to cases who feed on self-prepared meals, although statistical significance was observed only in male. In addition, they have also found that the difference in BMR is associated with coordinated responses to cold exposure (Maeda et al. 2007). As a result, males with a lower BMR indicate a higher metabolic rate with a higher forearm blood flow. In other words, males with a lower BMR easily increase heat production due to greater body heat loss during cold exposure. This is not a valid case for consideration of phenotypic responses.

A summary of the previous studies by Maeda et al. between 2005 and 2007 shows two different coordinated responses to cold stress related to daily behavioral pattern: low- and high-BMR types. At least in the case of males, the low-BMR type tends to follow a certain stereotypic lifestyle practices such as eating snacks between meals, displaying low physical activity and feeding on food purchased at convenient stores; viz., exhibiting low insulation and high metabolic rate. It may be a not-bad response at most in a mild cold stress; however, the response cannot be categorized as a phenotypic adjustment to a severe cold stress. The high-BMR type tends to not eat between meals, displaying high physical activity and feed on self-prepared food viz., showing high insulation and low increase in heat production.

While the low-BMR type subjects are not valid, the hight-BMR type cases are treated as valid for adjustment. All in these different phenotypic response may be dominantly molded by the acquired behavioral history.

3.2 Variation in orthostatic response related to physical activity

Those human subjects who routinely display low physical activity tend to exhibit low maximum oxygen intake, which can actually be improved with aerobic training **(**Buskirk et al., 1957; Astrand and Rodahl, 1970) via increase in the cardiorespiratory endurance (Taylor et al.,1955). This is a good example of actualization of functional latency in aerobic ability.

Orthostatic response is very important function to keep blood pressure against change in gravitational effect on cardiovascular system due to postural change. It has been reported that orthostatic tolerance was elevated after physical training (Fortney et al.,1992; Raven et al., 1984). According to Aoki (2007), not only an increase of maximum oxygen intake but the orthostatic tolerance evaluated from head- up tilting with constant cardiac output accompanying by lowered

HR and increased stroke volume are also established by 12-week aerobic training in sedentary subjects. The subjects were instructed to perform exercise for 30 minutes at load of 60% Vo2max, 3 times a week for 12 weeks. Furthermore, detraining for a 12-month period followed by 3-month aerobic training did not affect the characteristic orthostatic responses to head-up tilt even when the aerobic ability is reduced significant. Based on these findings, although elevated physical activity levels actualize the functional latent parts of aerobic ability and orthostatic tolerance, possible differences in the persistent period exist between dynamic functions and anti-gravity static functions related with maximum capacity while the same cardiovascular system associated with both functions.

3.3 Seasonal variation in light-induced nocturnal melatonin suppression

Melatonin is an important hormone related to circadian rhythm, sleep, and other serious diseases and functional deterioration including cancer, Alzheimer's disease, osteoporosis and so on (McArthur et al.,1996; Suzuki & Hattori, 2002; Wu et al.,2003). This melatonin release is promoted during nighttime without lighting, but the nocturnal melatonin release is suppressed by the artificial light. However, the extent of this nocturnal suppression depends on condition of diurnal light exposure as well (Park et al.,1999; Hebert et al.,2002). In a study by Torigoe et al. (2007), the nocturnal suppression of melatonin is lower in subjects who exposed to higher light-intensity in a morning than those exposed to lower light-intensity in a morning. In a study by Higuchi et al. (2007) on the nighttime melatonin release in relation to seasonal differences, the suppression rate of melatonin release under lighting at night is greater in winter than summer, which might be caused by elevated sensitivity to light due to lower intensity of light and short daytime in winter.

Based on these findings, human subjects who spend more time inside their houses and buildings during daily daytime activity, especially those who work in basements with slim chances of exposure to natural lighting, probably decreased nocturnal melatonin secretion and increased suppression of melatonin even in summer when exposed to nighttime lighting. The actual state and extent of non-visual effects of light exposure, the absence of seasonal changes and its effect in daily life activity remains currently unknown. As for understanding the mechanisms involved in adaptability to the modern civilization-dependent living environments, detailed studies involving the various socio-scientific perspectives are warranted.

4. SUMMARY

Fig. 3 shows summary of the three keywords and its relation to human behavior and biological adaptability. The subject of physiological polytypism is composed of whole-body coordination and functional potentiality, which is corresponding to apparent part and latent part, respectively, both of two indicate physical resources in functional part. Degree of apparent part or the border line between apparent and latent parts shown in Fig. 3 is movable, affected by the acquired behavioral history by individual intention.

Human behavior in a highly technological environment based on emotion tends to depend on cultural medium accompanied by sedentary lifestyle, which would move the border line and result in affecting biological adaptability to the environment, such as changes in BMR and cardiovascular response associated with cold and orthostatic tolerances, degrees of melatonin release and suppression at nighttime, and etc above mentioned.

Conclusion: We need to consider the balance between human behavior based on emotion and highly technological environment to keep biological adaptability in good condition. In other words, we need to improve environmental design and to have some biological guideline for human behavior by cooperation with physiological anthropologist and environmental designer.

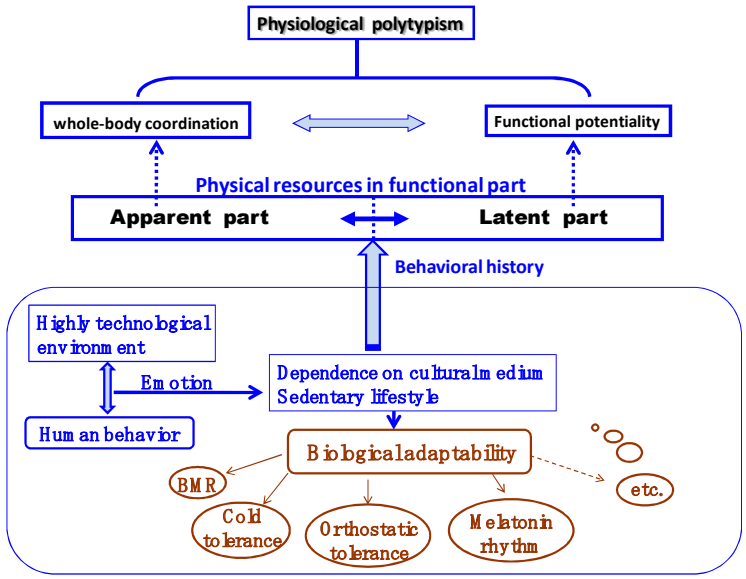

Figure 3: Summary of the three keywords and its relation to human behavior and biological adaptability.

5. REFERENCES

Aoki, K. (2008). Effects of physical training on cardiovascular responses to head-up tilt in sedentary men. Ph.D diss., Kyushu Univ. (in Japanese)

Astrand P-O., & Rodahl, K. (1970). Textbook of work physiology. McGraw-Hill, Inc. New York.

Buskirk, E. & Taylor, H. L. (1957). Maximal oxygen intake and its relation to body composition, with special reference to chronic physical activity and obesity. J. Appl. Physiol. 11:72-78.

Fortney, S.,Tankersley, C., Lightfoot, J.T., et al., (1992). Cardiovascular responses to lower body negative pressure in trained and untrained older men. J Appl Physiol 73:2693- 2700

Hebert, M., Martin, S.K., Lee, C. et al. (2002). The effect of prior light history on the suppression of melatonin by light in humans. J. Pineal research 33:198-203.

Higuchi, S., Motohashi, Y., Maeda, T. et al. (2007). Less exposure to daily ambient light in winter increases sensitivity of melatonin to light suppression. Chronobiol Int. 24:31-43.

Maeda, T., Fukushima,T., Ishibashi, K. et al. (2007). Involvement of basal metabolic rate in determination of type of cold tolerance. J. Physiol. Anthropol., 26:415-418.

Maeda, M., Sugawara, A., Fukushima, T. et al. (2005).Effects of lifestyle, body composition, and physical fitness on cold tolerance in humans. J. Physiol. Anthropol. Appl. Human Sci., 24 :439-443.

McArthur A.J.,Lewy, A.J., & Sack, R.L. (1996). Non-24-sleep-wake syndrome in a sighted man: circadian rhythm studies and efficiency of melatonin treatment. Sleep, 19:544-553

Park, S. J., & Tokura, H. (1999). Bright light exposure during the daytime affects circadian rhythms of urinary melatonin and salivary immunoglobulin A. Chronobiol. Int., 16:359-371.

Precht, H. (1958). Concepts of the temperature adaptation of unchanging reaction systems of cold-blooded animals. In *Physiological Adaptation*, ed. C. L. Prosser, American Physiological Society, Washington, DC.

Raven, P.B., Young, D.R., & Blomaqvist, C.G. (1984). Physical fitness and cardiovascular response to lower body negative pressure. J Appl Physiol 56:138-144

Sato, M. (2005). The development of conceptual framework in physiological anthropology. J. Physiol. Anthropol. 24:289-295.

Suzuki, N. & Hattori, A. (2002). Melatonin suppression osteoclastic and osteoblastic activities in the scales of goldfish. J Pineal Res 33:253-258

Torigoe, H., Kozaki, T. & Yasukouchi, A. (2007). Effect of sunlight on light-induced suppression of nocturnal melatonin. Jap. J. Physiol. Anthrop. 12(Suppl 2):100-101.

Wu, Y.H., Feenstra, M.G.P., Zhou, J.N., et al. (2003). Molecular changes underlying reduced pineal melatonin levels in Alzheimer disease: alterations in preclinical and clinical stages. J Clin Endocrinol Metab 88:5898-590

Yasukouchi, A. (2005). A perspective on the diversity of human adaptability. J Physiol Anthropol Appl Human Sci 24: 243-247.2005

Socio-Economic and Geographic Factors in Human Variation

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ABSTRACT

An integrated and multidisciplinary approach to understanding human variation and its bases is essential and productive. Such an integrated approach in the context of population, environment, social and cultural frameworks, and evolutionary perspectives properly rests within the field of anthropology. Two factors that contribute substantially to human variation are social position within a society and geographic position within space. The former carries with it influences of the social and cultural environment, while the latter incorporates influences of a complex of the physical, biotic, and human-transformed environment. In both cases, access to resources – that is intellectual and cultural and material resources -- transforms the genetic base and phenotypic expression of the individual throughout its life from conception (or before) to death. In the U.S., Franz Boas recognized the power of the environment to contribute to human variation over a century ago. Since that time, there has been considerable research conducted on the effects of socio-economic factors on human variation through health. Geographic variation was explored within the framework of "race" during the early 20th century, whereas contemporary studies of human variation have focused on human adaptation of the population to environmental characteristics that distinguish different geographic areas. These factors that impact human variation will be discussed as biobehavioral outcomes of complex environmental processes.

1. INTRODUCTION

Socio-economic and geographic influences on human variation are extensive and can modify the human phenotype in the short-range, medium-range, and/or long-range. Socio-economic influences are likely not to play a major role in genetic selection processes because the cultural factors leading to Darwinian selection are likely to be brief in the context of evolutionary time. Geographic influences on human variation, on the other hand, may have evolutionary significance because geographic influences (climate, elevation, solar radiation, soil content, food availability, disease vectors, etc.) may be long lasting. One productive way to study environmental influences on human variation is through studies of developmental plasticity such as the *Lifespan or Life History Approach*. The *lifespan approach* is an organizational framework to explore relationships among different stages or periods of the human life from conception to death. Not only do earlier periods influence later periods, but values and behaviors of adults can influence health and variation of progeny at younger ages. Three premises are: (1) the *lifespan approach* is a paradigm or perspective, not a theory; (2) it is biobehavioral and holistic in scope; and (3) the whole lifespan is the frame of reference (Leidy 1996).

It is understood that the geographic and socio-economic environment are interactive, but that the scope of geographic variation in human populations is enormous. Hence, this paper will focus more on socio-economic influences on human variation from the perspective of growth and development and from a lifespan approach than on geographic influences.

Some of the earliest studies exploring the effects of socio-economic factors on human variation were conducted by Franz Boas in studies of the growth of children and on migrants from Europe to the United States (Boas 1940). Some of his findings included the following:

- There were increases in height and slight changes in cephalic index in migrants compared to sedentary individuals (Boas 1912).
- A negative relationship existed between family size and average heights of children at given ages (Boas 1940).
- Children from the Horace Mann School of Columbia University had become larger between 1909 and 1935 (now known as the secular trend in growth). He attributed this to changes in social and economic conditions leading to modification of the "tempo of development" of children (Boas 1935).
- His knowledge of "growth tempo" (rates) enabled him to understand biological plasticity in growth (Boas 1930, 1935).

Franz Boas was a pioneer in discovering and documenting the concept of *plasticity* in humans, that is the capacity to *adapt* to a variety of environmental circumstances through growth or developmental; process. Examples of this include:

(1) differences in the "tempos of growth" (velocities) among children of different socio-economic classes; (2) the negative growth effect of large sibships in poor families with limited resources; (3) geographic differences in child growth associated with both ethnicity and socio-economic conditions; and (4) temporal changes in child growth patterns linked to short-term and long-term economic trends and limited resources (secular trends).

2. SOCIO-CULTURAL FACTORS THAT INFLUENCE HEALTH AND BIOLOGICAL FITNESS

Figure 1 shows some major life events that can contribute to human variation throughout the life cycle. As the individual ages from conception through infancy, opportunities for developmental plasticity or adaptation decrease – the individual becomes more "canalized" or channeled into a specific growth trajectory (Little 1995). Human societies are able to modify or construct their own environment or "cultural-environmental niche," that is the complex set of environmental parameters that define the cultural circumstances of an individual's life (Wells 2007). Several examples of environ-mental influences on prenatal development are nutrition, work requirements, hygiene, disease exposure, and levels of impoverishment – many of these influences are culturally mediated.

Influences of socioeconomic class on body size were demonstrated in a study of Scottish children aged 11 years in the early 1950s (in Tanner 1962: 138). A gradient existed where children of professional class fathers were about 3 cm taller and 1-2 kg heavier than children of manual workers. As with Boas's (1940) earlier research, there was also an inverse relationship between size of the sibships and size of the children, but it was most pronounced in the lower socioeconomic classes. Lasker and Mascie-Taylor (1989) based their study on data drawn from the National Child Development Study of all children in England, Scotland and Wales during the 3rd-9th of March 1958. Longitudinal follow-up studies were conducted of children at 7, 11, and 16 years of age on a sample size of ~ 16,000 (see Figure 2). Social class designations were based on the occupation of the male head of household. Differences in height between children from difference occupational classes were achieved by 7 years of age and very little height differential was acquired after that age. Goldstein (1971), working with the same data, found that mother's height, age, and smoking habits and the child's birthweight, gestation length and number of younger siblings accounted for 60% of the difference between upper and lower classes in 7-year-olds. Mascie-Taylor (1984) showed that upwardly mobile children were smaller than their new higher class but larger for the previous socio-economic class.

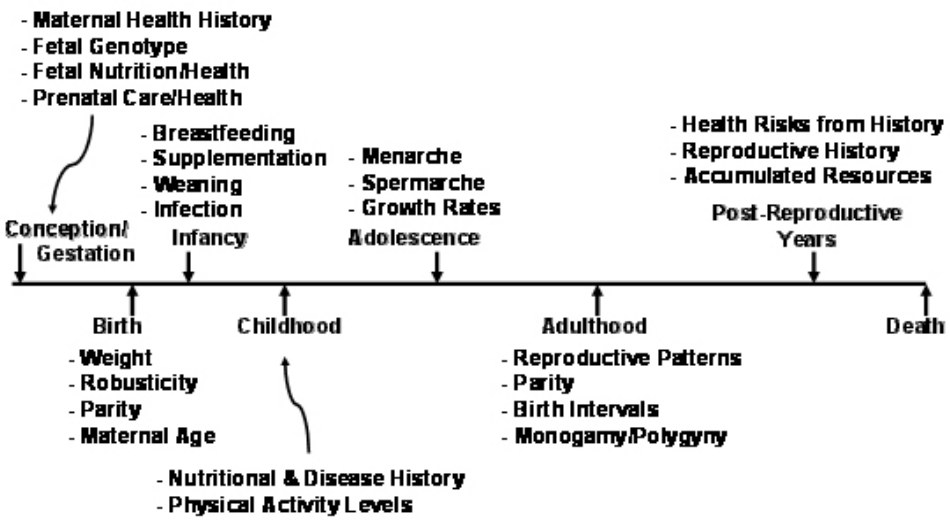

Figure 1: Life events contributing to human variation

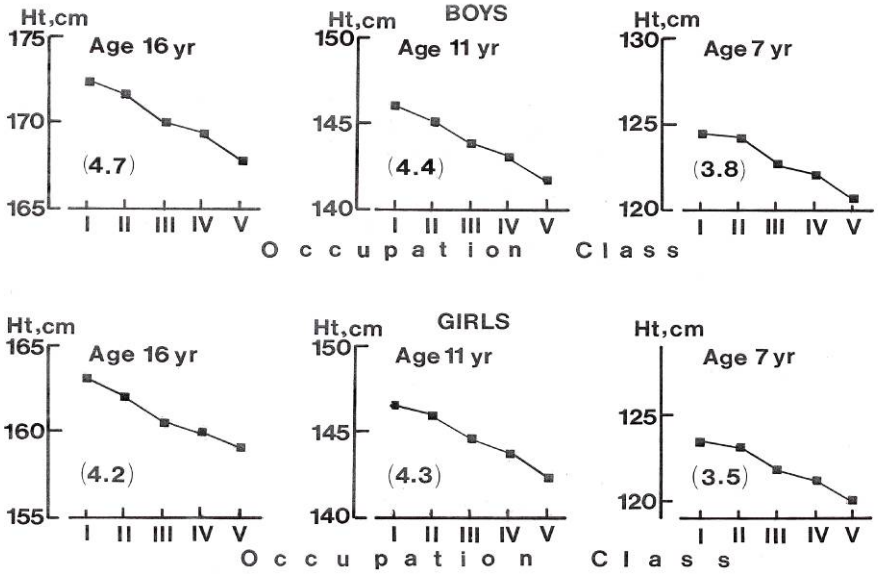

Figure 2: Social class and growth in Britain (data from Lasker and Mascie-Taylor 1989)

3. SECULAR TRENDS AS INDICATORS OF SOCIO-ECONOMIC CONDITIONS

Secular trends were first identified as short-term effects of environmental change that began sometime in the late 18th or early 19th centuries in Western industrialized nations. These trends were almost certainly linked to economic improvements associated with the Industrial Revolution. There have been numerous studies documenting these secular trends, but several stand out. Most have documented increases in body size of children at all ages between 18th century and the present, but there were maturation trends that took place, as well. For example, Tanner (1962:153) compiled data in girls that demonstrated declines in age of menarche from about 17 years in 1800 to about 13 years in 1960. For boys, Daw (1970) found secular trends during the mid-1800th century where voice breaking (linked to puberty) in J.S. Bach's Leipzig choristers ranged between 17 and 18 years. In mid-20th century London choir boys, puberty was much earlier with voice breaking at 13.3 years. Finally, Floud et al. (1990) drew on data from 1750 up to 1950 that illustrated effects of both short-term and longer-term economic trends on the stature of British working-class boys who were recruits from the Marine Society and boys from the Royal Military Academy at Sandhurst. British working class 15-year-olds gained nearly 30 cm in height over the 200-year period, while upper-class boys gained only about 10 cm.

4. THE "FETAL ORIGINS HYPOTHESIS" AND DEVELOPMENTA L ORIGINS OF HEALTH AND DISEASE

The "fetal origins hypothesis" was formulated by David Barker (1998) and states that some adult-onset diseases are associated with growth patterns during gestation and infancy. The adult-onset diseases include heart, circulatory, renal, and pancreatic diseases linked to cardiovascular diseases, type II diabetes (NIDDM), and hypertension (metabolic syndrome). Barker found that lower birth weight babies had higher prevalence of these diseases as adults than babies with normal or higher birth weights. In what was later called the "thrifty phenotype hypothesis," Hales and Barker (2001) postulated the following sequence: (1) poor maternal nutrition leads to fetal growth retardation; (2) lower birth weight (from fetal retardation) is linked to adult cardiovascular and renal disease and NIDDM; (3) fetal retardation and lower birth weight result in a developmental adaptation (*plasticity*) to limited resources; and (4) later catch-up growth and increase in body size (above birth percentile ranking) may be harmful or maladaptive and predispose the individual to adult-onset diseases. A model for some of these processes is given in Figure 3 (Gluckman et al. 2007). What is most striking about this sequence of events is the *transgenerational* aspect of the process, where maternal malnutrition is inherited.

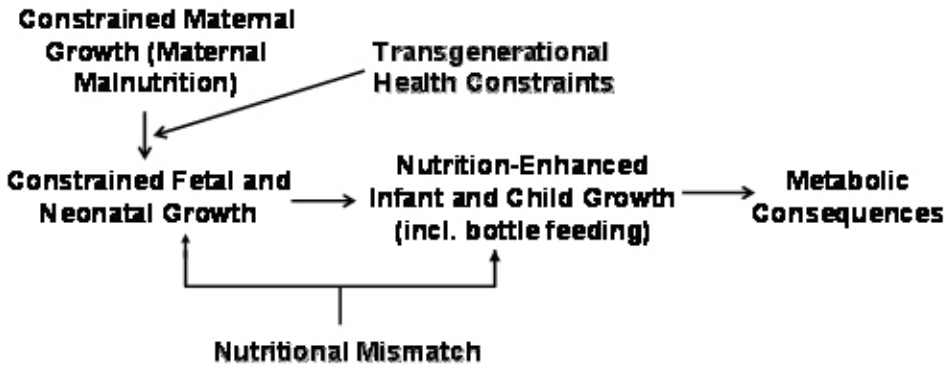

Figure 3: A model for the "Developmental Origins of Health and Disease (modified from Gluckman 2007)

One example of the dramatic birth weight changes that have taken place in history is given in Figure 4. This figure shows birth weights of poor Dublin infants between 1870 and 1930. Birth weights during an economic downturn were as low as 3200g, but averaged between 3300 and 3400g during most times. There was considerable year-to-year variation in this series from Dublin.

Mean birth weights show among-population variation from less than 2500g to more than 3700g (Meredith 1970), whereas within-population variation is much greater. Based on large numbers of lower-class and poorly nourished women with minimal prenatal care in Western nations when coupled with the rise in obesity that is so prevalent now in the West, there is likely to be a continuing increase in diseases associated with the metabolic disorder. And this syndrome of diseases will remain as a constellation directly linked to socio-economic class and to poverty.

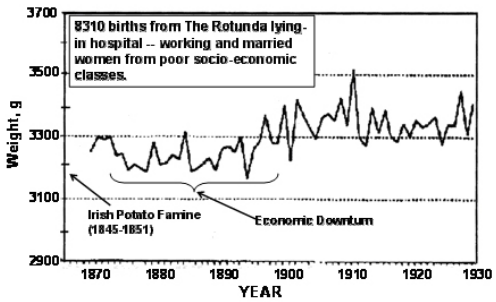

Figure 4: Dublin birth weights 1870-1930 (modified from Ward 1993)

5. SUMMARY

Socio-economic status can be defined by a complex variety of factors including family history, social position, role definition, ascribed and achieved status, occupation, material wealth, and other variables. Different levels of socio-economic status carry with them a variety of health advantages and disadvantages that are a part of the life experience. Social mobility can influence some of the factors (Mascie-Taylor 1984) related to health status, but mobility can not transform life history.

Figure 5 represents some of the variables influencing health and enhancing health risks in low socio-economic status individuals. The "thrifty phenotype hypothesis" predicts the effects of poor maternal health of fetal growth and metabolic diseases of adulthood. If poverty during gestation is followed by poverty in infancy and childhood, then small size may carry with it lowered work capacity and decreased cognitive ability. Childhood morbidity is a concomitant of poverty and will increase risk factors in later life. Limited education ensures limited opportunities for upward mobility and improvements in living standard and life style. High stress levels from low socio-economic status lead to stress disorders such as hypertension and cardiovascular disease and are likely to be associated with habitual excess in drug use and eating disorder. All of these factors are correlated and underline the importance of socio-economic status as a crucial element in health and human variation.

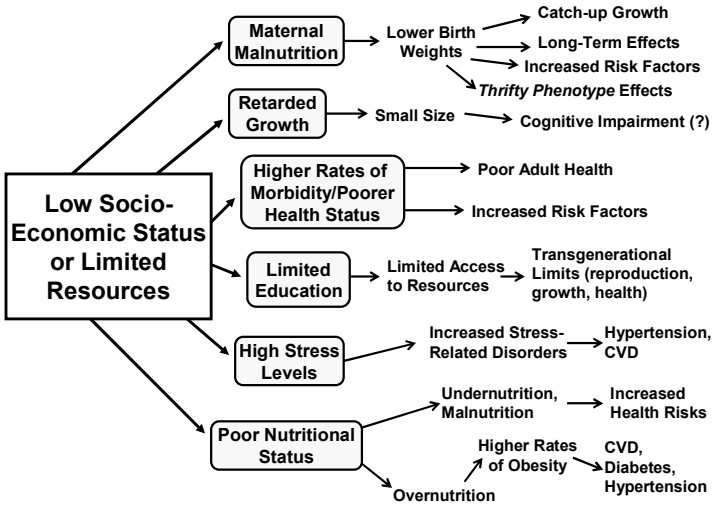

Figure 5: Relationships among low socio-economic status or limited resources and outcomes in health and human variation

ACKNOWLEGMENTS

I wish to thank the organizers of the 9th International Congress of Physiological Anthropology (ICPA 2008, *Human Diversity: Design for Life*) for inviting me to Delft in The Netherlands for the Congress. I want to particularly acknowledge the hospitality of the Conference Chair, Dr. Johan F.M. Molenbroek and his colleagues at the Technical University of Delft. I also wish to thank the organizers of the Congress: Nicholas Mascie-Taylor, Akira Yasukouchi, Hajime Harada, Miriam Reitenbach, Tommy Louts, and Sonja van Grinsven-Evers. Delft is an old and lovely city that I enjoyed visiting.

6. REFERENCES

Leidy, L. (1996). Lifespan approach to the study of human biology: an introductory overview. *American Journal of Human Biology* 8: 699-702.

Boas, F. (1940). *Race, Language and Culture*. New York: Macmillan.

Boas, F. (1912). *Changes in Bodily Form of Descendants of Immigrants*. New York: Columbia University Press.

Boas, F. (1935). The tempo of growth of fraternities. *Proceedings of the National Academy of Sciences* 21: 413-418.

Boas, F. (1930). Observations on the growth of children. *Science* 72: 44-48.

Little, M.A. (1995). Adaptation, adaptability, and multidisciplinary research. In: Biological Anthropology: The State of the Science, ed. by N.T. Boaz and L.D. Wolfe, pp. 121-147. Bend, Oregon: International Institute for Human Evolutionary Research.

Wells, J.C.K. 2007. The thrifty phenotype as an adaptive maternal effect. *Biological Reviews* 82: 143-172.

Tanner, J.M. 1962. *Growth at Adolescence.* Blackwell, Oxford.

Mascie-Taylor, C.G.N. 1984. The interaction between geographical and social mobility. In: *Migration and Mobility*, ed. by A.J. Boyce. Taylor and Francis, London.

Goldstein, H. 1971. Factors influencing the height of seven year old children – results from the National Child Development Study. *Human Biology* 43: 92-111.

Lasker, G.W. and C.G.N. Mascie-Taylor. 1989. Effects of social class and social mobility on growth in height, weight and body mass index in a British cohort. *Ann Hum. Biol*. 16(1):1-8.

Daw, S.F. (1970). Age of boys' puberty in Leipzig, 1727-49, as indicated by voice breaking in J.S. Bach's choir members. *Human Biology* 42: 87-89.

Floud, R., K. Wachter, and A. Gregory. (1990). *Height, Health, and History: Nutritional Status in the United Kingdom, 1750-1980*. Cambridge: Cambridge University Press.

Barker, D.J.P. (1998). *Mothers, Babies and Health in Later Life*. Edinburgh: Churchill Livingstone.

Hales, C.N. and D.J.P. Barker. 2001. The thrifty phenotype hypothesis. *Brit. Med Bull*. 60:5-20.

Gluckman, P.D., M.A. Hanson, and A.S. Beedle. 2007. Early life events and their consequences for later disease: a life history and evolutionary perspective. *Am. J. Hum. Biol*. 19(1):1-19.

Meredith, H.V. (1970). Body weight at birth of viable infants: a worldwide comparative treatise. *Human Biology* 42: 217-264.

Ward, W.P. 1993. *Birth Weight and Economic Growth*. Univ. of Chicago Press, Chicago.

Human Adaptation

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ABSTRACT

Following the success of the Human Genome Project, the subject of human variation and the adaptation of human populations to their environments has continued to attract substantial research interest. However, there also is ongoing controversy as to whether or not improved biological fitness via genetic selection should be regarded as the essential component of adaptation/adaptability, or equivalent weights should be given to physiological and cultural attributes. The profile and inheritance of skin colour-determining genes such as *ASIP* and *OCA2* in different human populations illustrate contrasting aspects of this issue. The implications and outcomes of adaptation under differing environmental settings are assessed in biological and cultural terms, with particular focus on four skin pigment-associated pathologies: skin cancers and melanoma, nutritional rickets in childhood, age-related osteomalacia, and oculocutaneous albinism.

1. INTRODUCTION

The study of human adaptability/adaptation has a long and distinguished tradition in the disciplines of Physical and Biological Anthropology and Human Biology, and formed a core topic of the International Biological Programme (IBP) which ran from 1964 to 1974. Within the 53 sub-themes of the IBP Human Adaptability programme, an estimated 800 expeditions and field visits were conducted on some 1.25 million individuals, with the theme 'Genetic Constitution' accounting for 23% of all investigations [1].

While these initial studies into human adaptation were largely influenced by the concept of Darwinian selection of specific gene variants, such as sickle cell trait [2], the development of Sociobiology during the 1970s and 1980s led to the roles of physiological or developmental adaptation and cultural adaptation being increasingly emphasized [3,4]. This change in emphasis resulted in the proposal that 'An adaptation can be considered as any characteristic of an organism that increases its fitness' [3].

Skin pigmentation studies provide a good framework for this inter-disciplinary approach to human adaptation, and as part of the IBP skin colour measurements were conducted in a wide range of populations from the Andes to the Arctic and the tropical Solomon Islands. However, in the wake of the Human Genome Project, most recent studies into skin colour variation have once again concentrated on the underlying role of genes, and to date 24 human pigmentation genes have been identified, dispersed across the human genome on chromosomes 2,3,5,6,9,11,12,13,15,20,22 [5].

2. THE PRIMARY BIOLOGICAL ROLE OF HUMAN SKIN PIGMENTATION

2.1 Skin colour and latitude

Anthropological studies have indicated that among indigenous populations, skin reflectance and hence dark skin colour is lowest at the Equator. In the Northern hemisphere an increase in skin reflectance of approximately 8.2% for every 10 degrees of altitude is observed for males and 8.1% for females. Comparable data for the Southern hemisphere are 3.3% for males and 4.7% for females, therefore suggesting higher UV radiation and darker skin colours at equivalent latitudes south of the Equator [6].

2.2 The nature and biological role of skin pigmentation

Skin colour is determined by the pigment melanin, which protects against potential mutational damage caused by ultra-violet (UV) radiation. Activation of the melanocortin-1 receptor (MC1R) promotes melanin production in the melanosomes in the dermis, with MATP and P proteins additionally contributing to pigment synthesis [7]. Melanosome size differs in individuals with dark, intermediate or light skins, and the melanosomes of dark skin also are more widely dispersed [7].

The level of UV protection afforded to an individual is proportional to the concentration of melanin in the dermis. In general, less melanin is required in the skin of individuals living at higher latitudes because of the lower levels of UV radiation they encounter in everyday life. However, exceptions do occur, for example, among peoples living in mountainous regions with consequent greater UV exposure.

3. SELECTION AGAINST SKIN PIGMENTATION

3.1 Recent negative selection pressures on human pigmentation genes

Single nucleotide polymorphism (SNP) studies on DNA samples from volunteers of sub-Saharan African, East Asian and European ancestry have identified recent positive selection at human pigmentation gene loci. In one such study based on ~800,000 SNPs, European skin colour was identified as subject to ongoing adaptive evolution, along with genes involved in fertility and reproduction, skeletal development, brain development and function, MHC-mediated immunity, and components of the electron transport chain [8]. By comparison, a similarly organized study using ~1.2 million SNPs identified 101 regions of the human genome, among them genes encoding pigmentation pathways, where a recent selective sweep had taken place and the genes had attained a frequency of ~100%, i.e., fixation of these mutations had occurred [9]. The question that arises is why such selection should have arisen, and specifically with respect to pigmentation genes, the nature of the advantages and disadvantages that have accrued?

3.2 Sunlight and Vitamin D synthesis

Although skin pigmentation is needed for protection against UV radiation in regions with high background UV levels, vitamin D synthesis is dependent on adequate exposure of 7-dehydrocholesterol in the skin to the UV component of sunlight. Where dietary vitamin D levels are marginal, melanin can prevent UV penetration and impede the activation of vitamin D, which is required for normal skeletal development and maintenance. Under these circumstances, it would be expected that mutations resulting in lighter skin colouration would be subject to positive mutation [10,11].

3.3 Inter-ethnic differences in skin colour gene profiles

The Out of Africa movement of humans predominantly involved migration to regions north of the Equator where, as previously indicated, UV radiation effects are lower than at equivalent southern latitudes [6]. As illustrated in Table 1, some genes appear to influence skin pigmentation in all human populations, whereas ancestry-specific genes have been described in African, European, South Asian and East Asian populations [12-15].

Table 1: The geographical distribution of skin pigmentation genes [5,12-15]

Genes	Populations
ASIP, OCA2, TYR	World-wide
ADTB3A	Africans
ASIP, SLC24A4, SLC24A5, IRF4, MATP	Europeans
SLC24A5, SLC45A2	South Asians
DCT	East Asians

The evidence to date suggests that the lightening of skin colour observed in Europeans and East Asians has resulted not from the expression of the same genes but via convergent evolution, enabling more efficient vitamin D mobilization from the diet in both ancestry groups [12].

4. SKIN PIGMENTATION DISORDERS

Four major skin pigment-associated pathologies affecting human populations can be identified:

4.1 Skin cancers and melanoma

There are three major types of human skin cancers: i) basal cell carcinoma, which is the most common form of human skin neoplasm and mainly affects people over 40 years of age; ii) squamous cell carcinoma in which cells in the surface epithelium develop into a malignant tumour; and iii) melanoma, which most frequently is associated with episodic sunburn and has a high risk of metastasis.

Within populations of European ancestry the incidence of cutaneous (malignant) melanoma has been doubling approximately every 10 years, with ~10% of cases familial. In part this reflects the changed lifestyle of many European and North American populations, with vacations taken in Mediterranean countries and tropical climates in which UV radiation levels are high. However, in Australia where a large majority of the non-indigenous population originated in north-west Europe, everyday exposure to high UV radiation is the major cause for the high rates of non-melanoma skin cancers [16-18].

Some 380,000 skin cancer cases are treated in Australia each year, representing 1.8% of the national population, and skin cancers are responsible for >80% of all new cancers. Melanoma is now the third most common cancer in men (after prostate cancer and bowel cancer) and in women (after breast cancer and bowel cancer), with >1,600 deaths per year [16-18].

Susceptibility to malignant melanoma is associated with a variety of genes located on different chromosomes, including the pigmentation genes *MC1R* (melanocortin 1 receptor), *OCA2* (oculocutaneous albinism 2), *ASIP* (agouti

signalling protein) and *TYR* (tyrosinase) [19,20]. Two additional highly penetrant melanoma-predisposing genes recently have been described, *CDKN2A* and *CDK4*, and a genome-wide study has indicated a melanoma risk locus on chromosome 20q11.22 in early-onset cases of the disease [21].

4.2 Nutritional rickets in childhood

As noted in section 3.2, vitamin D is mainly synthesized via the action of sunlight. Childhood rickets, which was common in urban Europe and North America in the 19th and early 20th centuries, is caused by hypovitaminosis D, which in turn results from inadequate diet and the poor environmental living conditions that prevailed in countries undergoing industrialization [22,23].

Nutritional rickets was reported in U.K. South Asian children in the 1970s, with the most severe cases observed among Hindu children on a strict vegetarian diet, including a high intake of *chappatti* (unleavened bread) [24]. Subsequent research has indicated that this problem has persisted in the U.K. [25-27], and even in Australia with a high level of intense sunlight, immigrant Asian and African children are at increased risk of rickets [28].

In the U.K. an estimated 94% of otherwise healthy adult Pakistani females were found to be vitamin D-deficient, and similar low vitamin D levels have been described in Pakistani women resident in Norway [29,30]. Pakistani mothers with low 25-hydroxy vitamin D3 levels had smaller babies, indicating poorer fetal growth because of lower serum calcium and phosphate, and secondary hypothyroidism due to elevated serum parathyroid hormone (PTH) levels [30].

It appears that this problem is much more widespread than previously suspected. For example, low vitamin D levels have been observed among Muslim Bedouin and Ultra-Orthodox Jewish mothers in Israel. As both of these communities prescribe very modest clothing for females, whose lives are largely conducted indoors, the underlying cause of the problem would appear to be inadequate exposure to sunlight, leading to reduced vitamin D synthesis [31].

4.3 Age-related osteomalacia

Over 30% of people >65 years of age in the U.K. are estimated to have vitamin D insufficiency [32]. In older people with osteomalacia there is a loss of skeletal mass caused by inadequate mineralisation of the normal osteoid tissue. However, among elderly stroke patients in Japan it was found that their decreased levels of bone mineral density and resultant osteoporosis could be successfully treated by simple exposure to sunlight [33].

In Australia, highly publicized and successful media campaigns are in place to ensure that people are aware of the risks of skin cancer from over-exposure to UV radiation. Unfortunately, over-avoidance of sunlight by older people has led to increasing levels of osteomalacia, since many persons in the >65 year age group spend much of their lives indoors and so fail to synthesize adequate levels of vitamin D [34].

4.4 Oculocutaneous albinism (OCA)

Two main types of oculocutaneous albinism have been defined: i) OCA1, in which affected individuals have mutations in the gene for the enzyme tyrosinase which catalyzes the first two steps of melanin biosynthesis, resulting in little or no pigment production in their skin; ii) OCA2, where individuals have some residual tyrosinase production, leading to fair to sandy coloured hair and light brown or occasionally light blue irises.

The overall prevalence of OCA2 in Sub-Saharan Africa has been estimated as 1/3,900 to 1/15,000 [35,36], but it can be much higher in certain tribes and clans, e.g., ~1/800 in the *Vhatavhatsindi* clan in Zimbabwe [37]. A 2.7 kilobase deletion is the common OCA2 mutation in Sub-Saharan African populations (and therefore also among African-Americans), but a range of other more rare mutations also have been described [35,38]. By comparison, the prevalence of OCA2 in the Native American Navaho tribe is due to a 122.5 kilobase deletion in the skin pigmentation P gene, with 1/1,500-1/2,000 persons affected [39].

In Sub-Saharan Africa there is strong physiological selection against persons with OCA2 due to their lack of protective melanin and heightened UV sensitivity, with consequent ocular problems and high rates of skin cancer [36]. The high rates of this disadvantageous mutation may therefore be due to genetic drift, and/or to positive cultural selection, as has been described in the *Vhatavhatsindi* and the Navaho.

Conversely, reports indicate that in East Africa negative cultural influences also apply, with active discrimination against people with OCA2. This discrimination recently has resulted in albinos ranging in age from babies to adults being murdered, with their hair, blood, skin and various body parts utilized by witchdoctors for the preparation of potions to bring financial success [40,41].

5. DISCUSSION AND CONCLUSIONS

Skin colour variation in human populations can be used both to inform discussion on the drivers of human adaptation and to pose questions relating

to adaptive evolution in the future. In terms of the inter-relationships between genetic, physiological and cultural determinants of human adaptation it would appear that all three factors are significant. This conclusion also can be drawn from the disruptional influence of long-distance migration and modern lifestyles on the previous balance between the advantageous and disadvantageous health outcomes of skin pigmentation, attained after many generations of selection. Thus in Australia there are high rates of skin cancer among European migrants and their descendants, whereas in South Asian children resident in the U.K. are more likely to suffer from nutritional rickets.

From a Physiological Anthropology perspective what remains to be established is whether in systems and pathways in which genetic variation still exists, e.g., with respect to skin colour in Europeans [8], evolutionary pressures may reverse or at least lessen in future generations. But what of systems which have attained genetic fixation, as also has been suggested for human pigmentation pathways [9]? With global warming and increasing UV levels, can cutaneous tissue adaptively increase the numbers of melanosomes through generational time? Or will future generations be dependent on the routine application of UV-blocking agents to minimize skin cancer, but at the potential cost of vitamin D insufficiency in women, rickets in their children, and osteomalacia in the elderly?

6. REFERENCES

[1] Collins, K.J. & Weiner, J.S. (1977). Human Adaptability, London: Taylor and Francis, pp. 1-23.

[2] Gould, S.J. & Lewontin RC. (1979). The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptionist programme. Proceedings of the Royal Society of London, series B, 205, 581-598.

[3] Barash, D.P. (1982). Sociobiology and Behavior. New York: Elsevier, 2nd ed., p. 24.

[4] Durham, W.H. (1991) Coevolution. Stanford: Stanford University Press, pp. 14-15.

[5] Myles, S., Somel, M., Tang, K., Kelso, J. & Stoneking, M. (2007) Identifying genes underlying skin pigmentation differences among human populations. Human Genetics 120, 613-621.

[6] Relethford, J.H. (1997), Hemispheric difference in human skin color. American Journal of Physical Anthropology 104, 449-457.

[7] Barsh, G.S. (2003). What controls variation in human skin color? PLoS Biology 1, 019-022.

[8] Voight, B.F., Kudaravalli, S., Wen, X. & Pritchard, J.K. (2006). A map of recent positive selection in the human genome. PLoS Biology 4, e72.

[9] Williamson, S.H., Hubisz, M.J., Clark, A.G., Payseur, B.A., Bustamente, C.D. & Nielsen, R. (2007). Localizing recent adaptive evolution in the human genome. PLoS Genetics 3, e90.

[10] Rana, B., Hewett-Emmett, D., Jin, L., Chang, B.H., Sambuughin, N., Lim, M. et al. (1999). High polymorphism at the human melanocortin 1 receptor locus. Genetics 151, 607-613.

[11] Jablonski, N.G. & Chaplin, G. (2000). The evolution of human skin coloration. Journal of Human Evolution 39, 57-106.

[12] Norton, H., Kittles, R.A., Parra, E., McKeigue, P., Mao, X., Cheng K. et al. (2006). Genetic evidence for the convergent evolution of light skin in Europeans and East Asians. Molecular Biology and Evolution 24, 71-722.

[13] Stokowski, R.P., Krishna Pant, P.V., Dadd, T., Fereday, A., Hinds, D.A., Jarman, C. et al. (2007). A genomewide association study of skin pigmentation in a South Asian population. American Journal of Human Genetics 81, 1119-1132.

[14] Sulem, P., Gudbjartsson, D.F., Stacey, S.N., Helgason, A., Rafnar, T., Magnusson, K.P. et al. (2007). Genetic determinants of hair, eye and skin pigmentation in Europeans. Nature Genetics 39, 1443-1452.

[15] Sulem, P., Gudbjartsson, D.F., Stacey, S.N., Helgason, A., Rafnar, T., Jakobsdottir, M. et al. (2008). Two newly identified genetic determinants of pigmentation in Europeans. Nature Genetics 40, 835-837.

[16] Australian Institute of Health and Welfare (AIHW) (2005). States and territories GRIM (General Record of Incidence of Mortality) Books. Canberra: AIHW.

[17] Australian Institute of Health and Welfare (AIHW) and Australasian Association of Cancer Registries (2007). Cancer in Australia: and overview, 2006. Cancer Series Number 37. Canberra: AIHW.

[18]Sunsmart (2008) Skin cancer overview. Retrieved 29.07.08 from http://www.sunsmart.com.au/browse.asp

[19] Jannot, A.-S., Meziani, R., Bertrand, G., Gérard, B., Descamps, V., Archimbaud, A. et al. (2005). Allele variations in the OCA2 gene (pink-eyed-dilution locus) are associated with genetic susceptibility to melanoma. European Journal of Human Genetics 13, 913-920.

[20] Gudbjartsson, D.F., Sulem, P., Stacey, S.N., Goldstein, A.M., Rafnar, T., Sigurgeirsson, B. et al. (2008). ASIP and TYR pigmentation variants associate with cutaneous melanoma and basal cell carcinoma. Nature Genetics 40, 886-891.

[21] Brown, K.M., MacGregor, S., Montgomery, G.W., Craig, D.W., Zhao, Z.Z., Iyadurai, K. et al. (2008), Common sequence variants on 20q11.22 confer melanoma susceptibility. Nature Genetics 40, 838-840.

[22] Allgrove, J. (2004). Is nutritional rickets returning? Archives of Disease in Childhood 89, 699-701.

[23] Rajakumar, K. & Thomas, S.B. (2005). Reemerging nutritional rickets: a historical perspective. Archives of Pediatric and Adolescent Medicine 159, 335-341.

[24] Dunnigan, M.G., Glekin, B.M., Henderson, J.B., McIntosh, W.B., Sumner, D. & Sutherland, G.R. (1985). Prevention

of rickets in Asian children: assessment of the Glasgow campaign. British Medical Journal 291, 239-242.

[25] Iqbal, S.J., Kaddam, I., Wassif, W., Nichol, F. & Walls, J. (1994). Continuing clinically severe vitamin D deficiency of Asians in the UK (Leicester). Postgraduate Medical Journal 70, 708-714.

[26] Shaw, N.J. & Pal, B.R. (2002). Vitamin D deficiency in UK Asian families: activating a new concern. Archives of Disease in Childhood 86, 147-149.

[27] Ladhani, S., Srinivasan, L., Buchanan, C. & Allgrove, J. (2004). Presentation of vitamin deficiency. Archives of Diseases in Childhood 89, 781-784.

[28] Robinson, P.D., Högler, W., Craig, M.E., Verge, C.F., Walker, J.L., Piper, A.C. et al. (2006). The re-emerging burden of rickets: a decade of experience from Sydney. Archives of Disease in Childhood 91, 564-568.

[29] Roy, D.K., Berry, J.L., Pye, S.R., Adams, J.E., Swarbrick, C.M., King, Y. et al. (2007). Vitamin D status and bone mass in UK South Asian women. Bone 40, 200-204.

[30] Brunvand, L., Quigstad, E., Urdal, P. & Haug, E. (1996). Vitamin deficiency and fetal growth. Early Human Development 45, 27-33.

[31] Weisman, Y. (2003). Vitamin D deficient rickets and osteomalacia in Israel. Israel Medical Association Journal 5, 289-290.

[32] Patient UK (2008). Vitamin D deficiency. Retrieved 29.07.08 from patient.co.uk/ showdoc/40001117

[33] Sato, Y., Metoki, N., Iwamoto, J. and Satoh, K. (2003). Amelioration of osteoporosis and hypovitaminosis D by sunlight exposure in stroke patients. Neurology 61, 338-342.

[34] Working Group of the Australian and New Zealand Bone and Mineral Society (2005). Vitamin D and adult bone health in Australia and New Zealand: a position statement. Medical Journal of Australia 182, 282-285.

[35] Stevens, G., van Beukering, J., Jenkins, T. & Ramsay, M. (1995). An intragenic deletion of the P gene is the common mutation causing tyrosinase-positive oculocutaneous albinism in southern African Negroids. American Journal of Human Genetics 56, 586-591.

[36] Hong, E.S., Zeeb, H. & Repacholi, M.H. (2006). Albinism in Africa as a public health issue. BMC Public Health 6, 212.

[37] Lund, P.M. (2005). Oculocutaneous albinism in southern Africa: population structure, health and genetic care. Annals of Human Biology 32, 168-173.

[38] Stevens, G., Ramsay, M & Jenkins, T. (1997). Oculocutaneous albinism (OCA2) in sub-Saharan Africa: distribution of the common 2.7 kb P gene deletion mutation. Human Genetics 99, 523-527.

[39] Yi, Z., Garrison, N., Cohen-Barak, O., Karafet, T.M., King, R.A., Erickson, R.P. et al. (2003). A 122.5-kilobase deletion of the P gene underlies the high prevalence of oculocutaneous albinism type 2 in the Navajo population. American Journal of Human Genetics 72, 62-72.

[40] Albinos, long shunned, face threat in Tanzania – The New York Times, 08.06.08. Retrieved 29.07.08 from www.nytimes.com/2008/06/08/world/africa/08albino/html.

[41] Living in fear: Tanzania's albinos. BBC, 21.07.08. Retrieved from news.bbc.co.uk/ 2/hi/Africa/7527729.stm

Task performance and joint angle changes in older females during a mouse pointing task

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ABSTRACT

We examined motor functions in older females during a mouse pointing task by measuring task performance and joint angle changes in the upper extremity. Eighteen older and 18 younger females with little computer experience performed a mouse pointing task. Results indicated that pointing time and number of clicking errors in older participants were significantly larger than those in younger participants. The values of index finger flexion, wrist ulnar/radial deviation and wrist extension were significantly greater in older than in younger participants. These results suggest that older participants manipulated the mouse with an awkward wrist posture, which may have led to poor motor control and pointing performance.

1. INTRODUCTION

Computers are now ubiquitous in modern society and have improved quality of life in numerous ways. Previous studies have suggested that computer technology provides older adults with opportunities to empower themselves psychologically [1, 2], and it is increasingly difficult for even older adults to avoid using computers in their daily lives [3]. Thus, the number of older adults who own computers or have experience in using computers has been rapidly increasing.

Despite the increase in computer use among older adults, there is still digital divide based on age [4, 5] and gender [6]. In Japan, adults aged 65 and over constituted about 21.5% of the population in 2007 [7], and are fastest growing age group. However, a survey on Internet use, which is the most common purpose of computer use, found that rate of use in the population aged 65 and over is substantively lower than that in younger and middle-aged adults. Gender differences also tend to become larger in the population of aged 60 and over [8]. Thus, the difficulties associated with computer use need to be reduced for older females in particular.

To facilitate computer usage and provide equal opportunity to receive benefits from computers for older females, it is necessary to understand the characteristics of their perceptual and motor functions while using computers. One possible barrier that could limit accessibility to computers is difficulty in manipulating the mouse, a common input device. Therefore, the purpose of this study was to examine perceptual and motor functions in older females during a mouse pointing task by measuring task performance and joint angle changes in the upper extremity.

2. METHODS

2.1 Participants

Eighteen older females (aged 60-72 years) and 18 younger females (aged 30-41 years) participated in this study. Participants reported having very limited experience with computer use. All participants reported being right-handed dominant, having sufficient sight and hearing and having no physical discomfort in the upper body regions. Prior to enrollment in the study, all participants provided written informed consent.

2.2 Experimental task

A 5 × 5-mm icon was presented in the center of a 17-inch liquid crystal display as the home target. Participants were asked to move the mouse cursor to the home target icon and click the left mouse button to start a trial. After clicking the button, the icon disappeared and a target icon (5 × 5 mm or 10 × 10 mm) was then presented on the perimeter of an imaginary circle with a radius of 50 mm from the icon. As illustrated in Figure 1, the target icon was presented at either 0° (right), 45° (top-right), 90° (top), 135° (top-left), 180° (left), 225° (bottom-left), 270° (bottom) and 315° (bottom-right) with equal probability. Participants were instructed to move the cursor to the target icon and click the left mouse button as quickly and accurately as possible.

Two independent variables were used in this study, target size and target location. A total of 80

trials were conducted. Mixed design repeated measures analysis of variance (ANOVA) were conducted for the between-subjects factor of group (younger vs. older) and the within-subjects factors of target size and location.

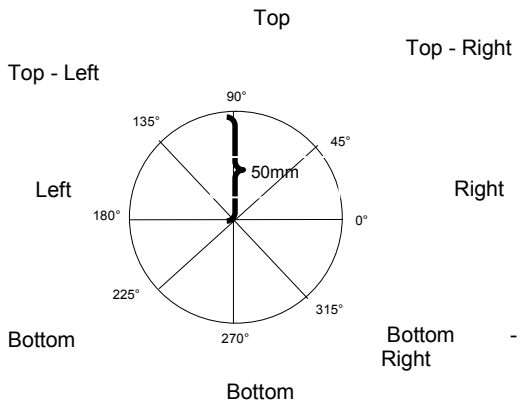

Figure 1: Target location

2.3 Measures

Pointing time and number of clicking errors were measured as performance parameters. To evaluate perceptual and motor functions while manipulating the mouse, joint angle changes in participants' right index finger, elbow and wrist were measured by an electrogoniometer (Biometrics Ltd., UK). Electrogoniometric signals were digitized at a sample frequency of 1 kHz, and flexion/extension angles of the index finger, flexion/extension angles of elbow, and flexion/ extension angles and ulnar/radial deviation angles of the wrist were derived with the AD conversion and data analysis system (DKH, Tokyo).

2.4 Experimental Procedure

The experiment was conducted in two sessions on different days. In the first session, participants given training in using the mouse and performing tasks. The second session was conducted for data collection. After completing practice trials for 5 minutes, electrogoniometric sensors were attached to participants' right index finger, right wrist, and right arm. After a 5-min break, participants performed 80 pointing trials.

3. RESULTS

3.1 Task performance

Pointing time for small and large targets are presented in Figures 2 and 3. A 2 (group) ×2 (target size) × 8 (target location) ANOVA for pointing time yielded a significant main effect for group, target size and target location ($F [1, 34] = 26.37$, $p<0.01$; $F [1, 34] = 55.30$, $p<0.01$; $F [7, 238] = 2.69$, $p<0.05$, respectively). Pointing times in older participants was significantly larger than those in younger participants. With regard to target size, pointing time for the small target was slower than that for the large target. Post-hoc comparisons among the eight target locations revealed that pointing time was significantly faster at the right than at the top-right and left target locations ($p<0.05$), and bottom-left, bottom and bottom-right target locations ($p<0.01$). Pointing time had significant interaction with group and target size location ($F [1, 34] = 58.40$, $p<0.01$). As a whole, pointing time in older participants was longer for the small than for the large target size, while that in younger participants did not changed remarkably with size.

For the number of clicking errors, A 2 × 8 within-subject ANOVA yielded a significant main effect for group, target size and location ($F[1, 34] = 8.86$, $p<0.01$; $F[1, 34] = 17.17$, $p<0.01$; $F[7, 238] = 2.77$, $p<0.01$, respectively). Older participants made significantly more errors than younger participants. The average of number of clicking errors for younger participants was markedly low for both target sizes (0.04 for the small target and 0.02 for the large target) compared to those for older participants (1.21 for the small target and 0.81 for the large target). With respect to location, older participants tended to make more errors when pointing to the targets at the bottom-left, bottom and bottom-right, although relatively large individual differences in number of errors were found for both large and small targets.

3.2 Joint angle changes

Table 1 shows the joint angle changes for older and younger participants. Data were analyzed by Student's t-test. The values of for index finger flexion, wrist ulnar/radial deviation and wrist extension were significantly higher in older participants ($t (34) = 2.22, 2.10, 2.44, 2.93$, respectively).

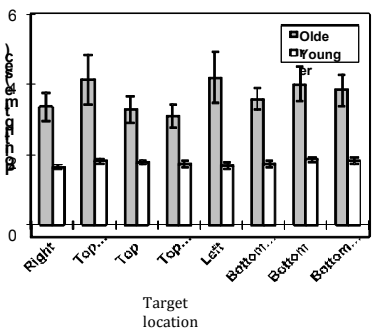

Figure 2: Pointing time for small targets (Mean ± S.E)

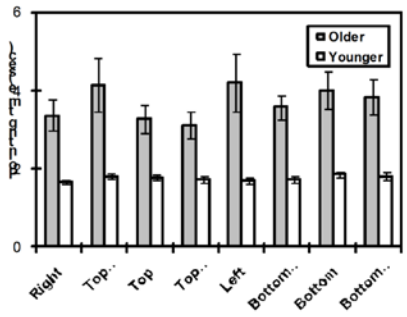

Figure 3: Pointing time for large targets (Mean ± S.E)

4. DISCUSSIONS

In our study, older participants had longer pointing times and a higher number of errors than younger participants. These results support the finding of a previous study which found that older adults had greater difficulty than younger adults in controlling a mouse cursor [9]. Thus, it is suggested that older participants had difficulty in controlling fine motor movements during mouse use.

With regard to joint angle changes, results demonstrated that the values of wrist extension and ulnar/radial deviation in older participants were greater than that in younger participants, that is, older participants used the mouse with awkward wrist postures. This indicates that older participants may have had difficulty keeping the mouse pointed straight ahead when moving the cursor to the presented targets in an oblique direction.

We also observed that older participants had difficulty clicking the mouse button because they were unable to hold the mouse with the thumb, ring and little fingers while clicking the button with the index finger. This resulted in an awkward wrist posture and a tendency to push the mouse forward with the palm, which may have induced slip errors. Thus, for older participants, dragging and clicking the mouse with an awkward wrist posture led to poor motor control, and the extent of the impact on task performance may have differed depending on the direction of movement.

Table 1: Joint angle changes (degrees)

	Older	Younger
Index finger	28.32 (1.18)	17.55 (2.10)
Wrist ulnar	15.88 (0.78)	14.09 (1.19)
Wrist radial	9.22 (0.41)	9.15 (1.34)
Wrist	27.71 (0.84)	20.72 (2.42)
Elbow flexion	53.14 (1.60)	58.61 (3.45)

*: p<.0.05 Mean (S.E.)

5. CONCLUSION

The present study clarified that older females had greater difficulty in mouse manipulation requiring fine motor control than younger adults. The observed awkward wrist posture in older participants may have led to poor work performance and potentially increased the risk for wrist injury. Therefore, further study is needed to identify design interventions that help minimize age-related performance differences and protect against mouse-related wrist injury. It is also necessary to conduct training intervention to help older adults learn the correct method of mouse manipulation to prevent wrist injury.

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7. REFERENCES

[1] White, H., McConnell, E., Clipp, E., Bynum, L., Teague, C., Navas, L., Craven, S., & Halbrechet, H. (1999). Surfing the net in later life: A review of the literature and pilot study of computer use and quality life. *Journal of Applied Gerontology*, 18, 358-378.

[2] White, H., McConnell, E., Clipp, E., Branch, L. G., Sloane, R., Pieper, C., & Box, T. L. (2002). A randomized controlled trial of the psychological impact of providing internet training and access to older adults. *Aging and Mental Health*, 6, 213-221.

[3] Morrell, R.W. (2002). Older adults, health information and the World Wide Web. Mahwah, NJ: Erlbaum.

[4] Ellis, R. D., & Allaire, J. C. (1999). Modeling computer interest in older adults: The role of age, education, computer knowledge, and computer anxiety. *Human Factors*, 41, 345-355.

[5] Czaja, S. J., & Lee, C. C. (2007). The impact of aging on access to technology, *Universal Access in the Information Society*, 5, 341-349.

[6] Cooper, J. (2006). The digital divide: the special case of gender, *Journal of Computer Assisted Learning*, 22, 320-334.

[7] Cabinet Office, Government of Japan. *Annual Report on the Aging Society: 2007*, retrieved November 7, 2008, from http://www8.cao.go.jp/kourei/whitepaper/w2008/zenbun/html/s1-1-1-01.html (in Japanese)

[8] Ministry of Internal Affairs and Communications, Japan. *2008WHITE PAPER Information and Communications in Japan*, retrieved November 7, 2008, from http://www.johotsusintokei.soumu.go.jp/whitepaper/eng/WP2008/chapter1-3.pdf

[9] Smith, M. W., Sharit, J., & Czaja, S. J. (1999). Aging motor control, and the performance of computer mouse tasks, *Human Factors*, 41, 389-396.

Individual differences in cerebral blood volume and oxygenation observed using a time-resolved near-infrared spectroscopy system during executions of a cognitive task

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ABSTRACT

A continuous wave near-infrared spectroscopy (CWS) system, measuring noninvasively cerebral blood volume and oxygenation during a cognitive task, is employed for optical topography. However, a device equipped with the system is unable to measure absolute values. On the other hand, time-resolved near-infrared spectroscopy (TRS) system has a great advantage that it measures absolute values of the blood volume and oxygenation. In the present study, using a device equipped with a TRS system, we examined individual differences in changes in the cerebral blood volume and oxygenation during two repetitive executions of a cognitive task. As a result, resting values with eyes closed, which were used as baseline values in changes in the cerebral blood volume and oxygenation, were highly reproducible in the two measurements and were found to include relatively small individual differences. On the other hand, changes in the cerebral blood volume and oxygenation from baseline during executions of the cognitive task have been proved to include large individual differences.

1. INTRODUCTION

We have so far reported changes in cerebral blood volume and oxygenation during a cognitive task by non-invasive measurements using a continuous wave near-infrared spectroscopy (CWS) system [1-4]. Although a CWS system made up of relatively simple parts is proved useful and is employed for optical topography [5, 6], a device equipped with the system is unable to measure absolute values, letting us hesitate to make comparisons among experiments and among subjects. On the other hand, time-resolved near-infrared spectroscopy (TRS) system [7] is difficult to make a measurement time into 10 seconds or less at the moment, because the system requires the integration time of photons, resulting in inadequate detection of a rapid change in hemodynamics. However, the system has a great advantage that it measures absolute values of blood volume and oxygenation. In the present study, using a device equipped with a TRS system, we examined individual differences in changes in the cerebral blood volume and oxygenation during two repetitive executions of a cognitive task.

2. METHODS

2.1 Subjects

Eighteen young healthy male volunteers with a mean age of 24.5 years participated in this study. All the subjects were right-handed normotensive nonsmokers. Informed consent was obtained from all the subjects before participation in the experiment. Subjects were instructed to refrain from taking alcohol and caffeine the night before the experiment and on the day of the experiment.

2.2 Measurement of Cerebral Hemoglobin Concentrations using a Near-infrared Spectroscopy System

Cerebral blood volume and oxygenation were measured using a TRS system. A device equipped with the TRS system consists of a light source of three-wavelength (760 nm, 795 nm, and 830 nm) laser light pulses and a light detector of a photomultiplier tube (TRS-20, Hamamatsu Photonics K. K., Hamamatsu, Japan) [8]. The TRS system allows determination of relative light-intensity, mean optical path length, scattering

coefficient, and absorption coefficient, enabling measurements of absolute concentrations of oxygenated hemoglobin ([oxy-Hb]), deoxygenated hemoglobin ([deoxy-Hb]), and total hemoglobin ([total-Hb] = [oxy-Hb] + [deoxy-Hb]). Two sets of optodes of the device with a source-detector distance of 4 cm were positioned on both sides of the forehead (immediately below the hairline) of a subject. Results derived from the left side of the forehead are reported in this study.

2.3 Cognitive Task

A five-color, computer-controlled version of a modified Stroop color-word task we developed was used as a cognitive task, and was partially described elsewhere [3]. Briefly, a subject is instructed to select one of five colored disks presented simultaneously with one color word on a computer screen, according to the instruction (i.e., "color" or "meaning"). The color of the presented word on the screen is discordant with the meaning of the word. The order of appearance of the instructions and color words is randomized. Subjects must overcome cognitive interference to respond properly. The original Stroop color-word task [9] has been demonstrated to actually activate the prefrontal cortex in a recent functional magnetic resonance imaging study [10].

2.4 Experimental Protocol

Two repetitive task-performing sessions (the first and the second) were administered as an experimental procedure. After a resting period, subjects participated in a 4-min performing session—the first session. After a 15-min break following the first task, subjects participated again in the second performing session—the second session. Each session consisted of the baseline (the last 2-min average of the resting period), the anticipation (2-min average), and the performance (4-min average). Baseline value and change, namely alteration of the 4-min averaged value during the performing session from the baseline, in each cerebral hemoglobin concentration were analyzed in this study.

Subjects were encouraged to do their best in the task to earn money prizes awarded to those according to the number of correct answers.

3. RESULTS AND DISCUSSION

3.1 Baseline Values

The mean and standard deviation (SD) of baseline value of each hemoglobin concentration in the first performing session was as shown in Table 1. Correlation coefficients between the baseline values in the first and second performing session were calculated to be 0.960-0.982 in each hemoglobin concentration, indicating that the baseline value was highly reproducible in the two repetitive performing sessions. These results indicated that the baseline values included relatively small individual differences and were stable.

Table 2: Baseline value of each hemoglobin concentration derived from the left side of the forehead (n=18)

	Oxy-Hb	Deoxy-Hb	Total-Hb
Mean (μM)	56.4	22.0	78.4
SD (μM)	6.4	3.3	8.8

3.2 Changes during Performing Session

On the other hand, as for the change in hemoglobin concentrations from the baseline during the performing session as 4-min averaged value, individual differences were large as shown in Figure 1. Subjects showed on the whole all combinations of increase and decrease in [oxy-Hb] and [deoxy-Hb], a typical change of increase in [oxy-Hb] and decrease in [deoxy-Hb] (such as in the first session in 8 out of 18 subjects) and an atypical change of decrease in [oxy-Hb] and increase in [deoxy-Hb] (such as in the first session in 3 out of 18 subjects), proving that cerebral hemodynamic response to the cognitive task includes large individual differences, which were similar to our previous findings observed using a CWS system (unpublished data).

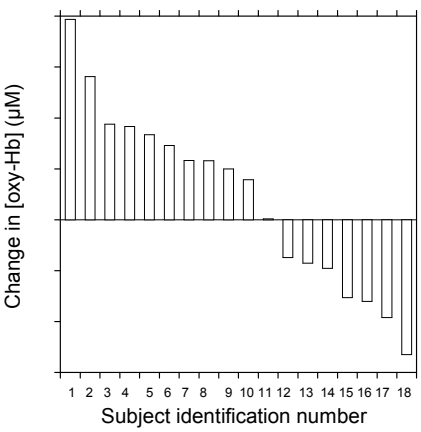

Figure 1: Change in oxy-Hb concentration derived from the left side of the forehead during the first performing session in all the subjects. Subject identification numbers were renumbered in order of the change in oxy-Hb concentration.

In addition, the mean of change in each hemoglobin concentration in the second performing session was decreased in terms of the amplitude compared with the value in the first performing session, such as from 0.42 μM in the first session to 0.07 μM in the second session in [oxy-Hb]. This result was also similar to changes in the cerebral hemoglobin concentrations observed in our previous studies using a CWS system during two repetitive executions of the cognitive task.

4. CONCLUSION

The results obtained in the present study using a TRS system demonstrated that individual differences in changes in the cerebral blood volume and oxygenation were large during two repetitive executions of a cognitive task, which were similar to our previous observations using a CWS system, although the resting values with eyes closed included relatively small individual differences.

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6. REFERENCES

[1] Shiraiwa, M., Hasegawa, K., & Niioka, T. (2000). Changes in the blood volume and oxygenation in the brain during a mental arithmetic task and their relationships to cardiovascular responses. *Therapeutic Research, 21*, 1516-1519.

[2] Niioka, T., Shiraiwa, M., & Hasegawa, K. (2001). Changes in the regional cerebral blood volume and oxygenation during a mental arithmetic task and their relationships to personality and stress coping traits. *Therapeutic Research*, *22*, 2004-2007.

[3] Niioka, T., & Sasaki, M. (2003). Individual cerebral hemodynamic response to caffeine was related to performance on a newly developed Stroop color-word task. *Optical Review, 10*, 607-608.

[4] Niioka, T., & Sasaki, M. (2004). Changes in cerebral hemodynamics during a cognitive task after caffeine ingestion. In M. Nakagawa, K. Hirata, Y. Koga & K. Nagata (Eds.), *Frontiers in Human Brain Topography* (Vol. International Congress Series 1270, pp. 299-301). Amsterdam: Elsevier B.V.

[5] Maki, A., Yamashita, Y., Ito, Y., Watanabe, E., Mayanagi, Y., & Koizumi, H. (1995). Spatial and temporal analysis of human motor activity using noninvasive NIR topography. *Medical Physics, 22*, 1997-2005.

[6] Koizumi, H., Yamamoto, T., Maki, A., Yamashita, Y., Sato, H., Kawaguchi, H., et al. (2003). Optical topography: practical problems and new applications. *Applied Optics, 42*, 3054-3062.

[7] Patterson, M.S., Chance, B., & Wilson, B.C. (1989). Time resolved reflectance and transmittance for the noninvasive measurement of tissue optical properties. *Applied Optics, 28*, 2332-2336.

[8] Oda, M., Nakano, T., Suzuki, A., Shimazu, K., Hirano, I., Shimomura, F., et al. (2000). Near-infrared time-resolved spectroscopy system for tissue oxygenation monitor. *Proc. SPIE, 4160*, 204-210.

[9] Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662.

[10] Adleman, N.E., Menon, V., Blasey, C.M., White, C.D., Warsofsky, I.S., Glover, G.H., et al. (2002). A developmental fMRI study of the Stroop Color-Word task. *NeuroImage, 16*, 61-75.

Anthropometry and design

Anthropometry and health

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ABSTRACT

For many years anthropometric indicators has been used to assess the nutritional and health status of individuals and populations and help in the decision for nutritional or health intervention. Various anthropometric measurements are used to assess either multiple risk factors of chronic disease like cancer, cardiovascular diseases, diabetes, or to predict an undesirable or desirable health outcome. Body mass index, waist to hip ratio or waist circumference are useful health indicators, easily collected, non-invasive and well accepted by the subjects whatever their age.

During pregnancy the main indicators to assess maternal and fetal health are based on gain of body weight of the mother at various stage of pregnancy and the detection of intra-uterine growth retardation (IUGR) in order to prevent an adverse outcome. Short stature of the mother, low pre-pregnant BMI and poor weight gain are all indicators of risk of IUGR and the risk can be amplified when these factors are associated to other non anthropometric indicators like maternal smoking during pregnancy or seasonality of food resources.

Growth monitoring is also a key element of follow-up for youngsters. Periodic assessment of child growth and checking of infant and children's health are based primarily on regular records of body weight and height compared to either national or international charts for the same gender and age. For infant newborn and less than 2 years of age, head circumference can also be an indicator of abnormal development.

Adolescent anthropometry is appropriate to track the timing of the adolescent growth spurt and maturation. It is an important period in human development influenced by inherited and environmental factors and it can easily be monitored with anthropometry.

Overweight in adults is now a major public health issue and the prevalence is dramatically increasing in developed as well as in developing countries. It is acknowledged that overweight in adults is often associated with increased morbidity and mortality. Percent body fat associated with specific fat distribution or modification in bone density are all likely to give precious information on the evolution of health with aging. For elderly, thinness and overweight are still anthropometric indicators of nutritional and health risk factors.

1. INTRODUCTION

Anthropometry was reported by a committee of experts as the single most universally applicable, inexpensive and non-invasive method available to assess human body characteristics like body size, body composition or fat content and their modifications with age for men and women or with reproductive status for women (WHO, 1995a). Anthropometric measurements and indices are extensively used in field surveys or clinical settings. Simple measurements like body weight and height give crucial health information at all ages. When they are combined to compute indices they can lead to precise indicators of overall health of individuals and populations. The use and advantages of anthropometry as health indicators at different ages, for example growth during infancy and adolescence (WHO, 1995b) or mother weight variation during pregnancy and lactation, or checking of health status during adulthood will be investigated in this paper.

Anthropometric monitoring in individuals are used to assess past or present threats to health, to predict various health risk factors linked with height, body weight, and/or body composition, to evaluate responses and benefit to interventions.

In addition to body weight, measured with a standard scale, and stature/height measured with a stadiometer, a number of skinfold thickness measurements (bicipital, tricipital, subscapular, supra-iliac) measured with a skinfold caliper, can be combined to assess percent body fat, then to compute fat mass and lean body mass for each individual. More sophisticated methods can be used in laboratories or clinical settings to measure total body composition or bone mineral density like hydrostatic weighing, bioelectrical impedence, dual energy X-ray absorptiometry (DEXA), magnetic resonance imaging (MRI), total body electrical conductivity (TOBEC). Some other methods can give more precise values of different body compartments (body water, body fat) like the use of doubly labelled water (DLW). The DLW method is based on the enrichment in stable isotopes of oxygen and hydrogen, already present in a very small quantity, and the follow-up of their elimination during the period after ingestion allowed to calculate total body water and to estimate fat free mass and consequently percentage body fat (Rosetta et al 2005).

2. MOTHER ANTHROPOMETRY DURING PREGNANCY AND FETAL GROWTH

During pregnancy the main indicators to assess maternal health and fetal growth are partly based on the gain of mother's body weight at various stages of pregnancy compared to her weight before or during the first trimester of pregnancy. Mothers' anthropometry is well adapted to evaluate fetal growth, easy to realize, even in rural settings or in very simple health centres, and is well accepted by the women. It is important even in deprived populations to make sure that the weight gain is adequate to sustain normal fetal growth (Nahar et al 2007). On the contrary in well-off societies the risk of mothers' post-partum overweight should be avoided as it may have long term consequences when the woman is not enough loosing weight after delivery (Callaway et al 2006).

The advantage to check the progression of mothers' body weight according to the term is to evaluate mother's capacity to deal with the energetic stress of pregnancy in chronically malnourished women, Anthropometry during pregnancy can be used to target the mother or the population for nutritional intervention (Begum et al 2007). and to detect intrauterine growth retardation (IUGR) which can happen even when a mother's weight is apparently normal but the risk is much higher in mother with low pre-pregnancy body mass index (BMI) (Neufeld et al 1999).

Some authors have pointed to the fact that health workers need to differentiate small for gestational age infants from "constitutionally small" infants (Mamelle et al. 2001) since one group is pathological the other one is not. Many recent studies have shown that low birthweight (LBW) and fetal growth restriction are a risk factor for a number of pathologies later in life (Hemachandra et al 2006). It was also mentioned that "women who delivered a LBW or IUGR infants were more likely to have fewer pregnancies, a history of previous LBW, lower pre-pregnancy weight and lower gestational weight gain » (Vega et al 1993).

Anthropometric follow-up can also help to detect a risk of prematurity, i.e. a baby born before 37 weeks of pregnancy. Mother care during the second half of pregnancy should help to identify mothers at risk of preterm labor, frequently women involved in strenuous physical work, repetitive tasks, standing position for long periods of time (Honest et al 2005). Although the number of premature infant is increasing with many factors like medical expertise, age of the mother, or parity . It is worse in the case of multiple births and the proportion of multiple birth is rising with the progress of medically assisted reproduction

3. BIRTH WEIGHT AND INFANT GROWTH

Premature babies often weight less than 2,500 grams (5 pounds 8 ounces) and they may be referred to as low birth weight (LBW). The mean birth weight in each country is associated with the improvement or not of the quality of mothers' health care and variations in socio-economic levels. For example, the record of mean birth weight in Scotland (Bonelli et al. 2008) has shown a steady increase from 1980 to the mid 1990s and a stabilisation during the more recent years. This is a trend seen in many developed countries. On the other hand poor developing countries still face severe risk of low birth weight (Horta et al 1997).

Recently a number of researchs have focused on the possible role of low birth weight to later outcome (Syddall et al. 2005). It was shown that birth weight ≤3000 grams is associated with higher risk of diabetes in adult life mainly in women, whatever the age (Lapidus et al 2008). Poor fetal growth followed by rapid infant growth is suspected to have an impact on adult metabolic diseases and cardiovascular risk in adults through an increase in childhood overweight and obesity (Hui et al 2008).

It was also reported that mothers exposed to the death of a relative during pregnancy or the six months before pregnancy gave birth to significantly smaller infants (Khashan et al 2008). In this process, the authors have pointed out the stress-related dysregulation of the hypothalamic-pituitary-adrenal axis

4. INFANT AND CHILD ANTHROPOMETRY AND NUTRITIONAL STATUS

Periodic Periodic assessment of child growth and checking of infant and children's health are based primarily on regular records of body weight and length/height compared to either national or international charts for the same gender and age. It was explained recently that infant growth during the first 6 months of life can influence later body composition, particularly rapid weight gain during early life (3-6 months of age) was likely to be related with higher adiposity later in life (Chomtho et al 2008).

In 2006 during a symposium called 'A new 21st Century International Growth Standard for Infant and Young Children' the World Health Organization has specified the most useful and

recommended standard to assess infant and children growth and nutritional status to the age of 5 (Onyango et al, 2007).

The most widely used health indicators for infant and children under 5 years of age are a combination of body weight, length and age recommended by WHO from 1995. a. Weight-for-age (W/A) or body mass relative to chronological age; a low W/A result from a low body weight for a normal length/height i.e. thin children, or children with a short stature for a normal body weight i.e. small children. This indicator cannot help to distinguish between the two possibilities but the proportion of children below a threshold of W/A give an indication on the community nutritional status. b. Weight-for-height/length (W/H) also called wasting or thinness is seen during severe food shortage or famine. c. Height/ length-for-age (H/A) reflects height relative to chronological age. Low H/A or stunting is also associated with poor socio-economic level in deprived populations.

Infant nutritional status can also be used as an indicator for the risk of mortality. For example in a Sahelian population studied during 2 consecutive years at the time of the "Great Drought", regular anthropometric measurements of the less than 5 years old children have shown a dramatic decrease in BMI at the time of full weaning, between 12 and 24 months of age, which anticipates a sharp rise in the age specific mortality at about 30 months of age (Rosetta & O'Quigley 1990).

The relationship between child anthropometry and mortality is still used in developing countries during emergency crisis like military conflicts or natural disasters. A fall in nutritional indicators is usually associated with an increased susceptibility to infectious or parasitic diseases (de Onis & Blössner 2000). We should mention that children in wartime are exposed to both direct injuries and privations during childhood.

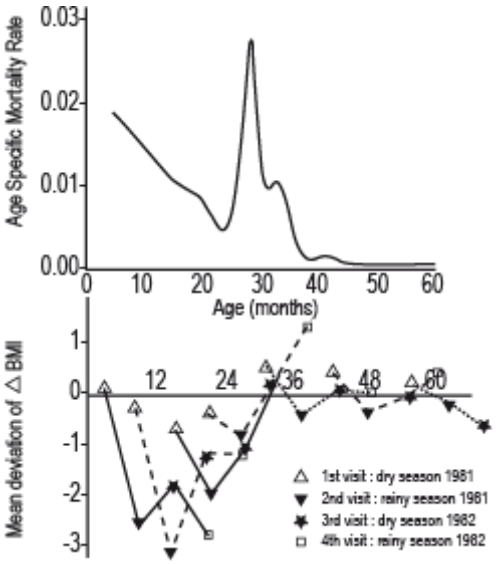

Figure 1: Mortality rate and variability in BMI for a sample of Serere infants in Senegal (from Rosetta & O'Quigley 1990 with permission)

5. ADOLESCENT ANTHRO-POMETRY AND SPECIFIC HEALTH PROBLEMS AT ADOLESCENCE

5.1 Obesity and related health complications

Anthropometry is currently used to check the adolescent growth spurt and maturation. It is also a useful method to detect abnormal height/length and abnormal body weight. Very short or very high stature can be detected early during adolescence and hopefully corrected when the cause is identified and possible to cure. "Short stature is not a disease in itself, but is used as a marker for a range of pathologies and as an indicator of general health status » (Fayter et al 2007).

The risk of obesity is now a matter of concern for children and parents all over the world. Adolescent change in body weight may be monitored in order to limit or prevent the risk of obesity (Ogden et al. 2008).

5.2 Detection of abnormal food behaviour

A loss of weight or a very low body weight should lead the parents and also the medical staff to search for any abnormal food behaviour (Herpertz-Dahlmann 2009). The incidence of

eating disorders like anorexia nervosa, bulimia or a combination of both is higher during adolescence than during adulthood and may be correlated with other psychiatric symptoms such as depression, anxiety disorder or schizophrenia. In these patients the abnormality of appetite control is frequently associated with a marked disturbance in body image and it is recognized that the onset of the disorder is often observed during adolescence.

5.3 Early pregnancy in adolescents

In a recent report the World Health Organization highlighted the great proportion of infants born from adolescent mothers (Bearinger et al 2007) and the health risk for mother and baby: "Babies born to girls aged 15-19 account for more than 10% of all births worldwide, and in many countries the risk of dying from pregnancy-related causes is twice as high for adolescents as it is for older mothers. Adolescents account for 13% of all maternal deaths" (WHO – UNFPA 2006). This is due to the fact that in adolescent girls who have not reached their final growth and maturation, adverse outcomes are related to the physical size of the mother and results in high cesarean section rates, puerperal infections or intrapartum complications, with a number of adverse outcome for the infant such as preterm birth, low birth weight and small for gestational age (Maryam & Ali 2008).

6. ADULT ANTHROPOMETRY AND RISK FACTORS OF CHRONIC DISEASES

Overweight in adults is often associated with increased morbidity and mortality. Change in body weight is an indicator at the individual level: an increase of weight can be correlated with metabolic modification, and a rapid decrease in body weight can lead to a check for sudden health conditions (Ringback Weitoft et al. 2008).

Height only was used as an indicator of health at the level of the population since it is partly an indicator for nutritional status and the socio-economic environment during childhood. Lung function is an important mediator of the association between height and cardio-respiratory condition. It was shown that greater height is associated with lower cardio-respiratory mortality in adults (Davey Smith et al 2000). Others have noted controversial results for the possible association between height and increased risk of several cancers unrelated to smoking. It seems that this association expresses the influence of calorie intake during childhood (Batty et al 2006). On the other hand height is negatively associated with the risk of coronary heart disease, stroke and respiratory death.

Mid arm circumference is measured with a tape measure at mid distance between the edge of the acromion process of the scapula and the top of the olecranon process on the left side for right-handed people. Lean arm circumference can easily be computed as (Lean arm circumference = arm circ. - (tric + bic skinf x $\pi/2$). Variations on the short term reflect the change in total energy balance: a decrease is associated with a sustained negative energy balance. As shown during two consecutive years in a population of sedentary agricultural workers in Senegal, the decrease and increase in lean arm circumference of adults followed clearly the seasonal variation in food reserves and the concomitant agricultural activity (Rosetta 1986). The time of plenty was also the period of low level of agricultural work. In contrast, the time of food shortage happens at the period of farming and harvest without any mechanical equipment. It means that men and women had to produce a high level of physical activity when they had a low level of energy intake, the combination of both factors resulting in a significant decrease in lean arm circumference.

A number of indices based on other anthropometric measures are widely used. Waist circumference (WC) determined between the lowest rib margin and the iliac crest with the subject standing and breathing normally is related with various metabolic risk factors according to age, gender or genetic characteristics. Hip circumference is measured at the level of greater trochanters and when combined with waist circumference give the waist-to-hip ratio (WHR) related to the level of abdominal obesity.

Both indices (WHR and WC) seems to have a strong association with the risk of hypertension in males and females with various cut-off points by gender, ethnicity and countries. "For example, Asians have increased metabolic risk at lower body mass indexes and with lower waist circumferences than other populations" (Ness-Abramof & Apovian 2008).

Body Mass Index (BMI) is calculated as bodyweight in kilograms divided by the square of height in meters. It is considered as a useful indicator of energy reserves in sedentary people and the limitation of its application to athletes, children, elderly and individuals with exceptional size has been identified many years ago (Garn 1997).

Normal BMI is defined between 18.5 and 24.9 for both genders, below 18.5 there is three grades of malnutrition: grade 1: 17.0-18.49; grade 2: 16.0-

16.99; grade 3: <16.0 and there is above 25 three grades of overweight: grade 1: 25.0-29.9; grade 2: 30.0-39.99; grade 3: ≥ 40.0. Overweight and obesity are considered to have adverse effect on several morbidity and mortality risk factors like cardiovascular disease, a number of cancer, and diabetes type 2, respiratory diseases (Calza et al. 2008). A systematic review of cohort studies published on the association between overweight/ mild obesity and cardiovascular mortality resulted in controversial issues due to the lack of discrimination of BMI between body fat and lean mass (Romero-corral et al 2006).

The combination of BMI with WHR and WC was recommended recently after a large European prospective study set up to assess the association between adiposity and the distribution of body fat with the prediction of risk of death (Pischon et al 2008).

In elderly also, anthropometric characteristics and variations are of great interest to assess the evolution of the nutritional status of sick elderly. Another chapter is dedicated to this specific population and this topic will not be developed here (see Crews this book).

To conclude, anthropometry is still an appreciated health indicator for individuals and populations. It is also a key element to assess the results of nutritional interventions at local or regional level and it provides very important indicators in nutritional surveillance

7. REFERENCES

[1] WHO Expert Committee (1995). Physical status: the use and interpretation of anthropometry. WHO Technical Report, Series N° 854.

[2] WHO Working Group on Infant Growth. (1995). An evaluation of infant growth: the use and interpretation of anthropometry in infants. Bulletin of the World Health Organization, 73, 165-174.

[3] Rosetta, L., Kurpad, A., Mascie-Taylor, C. G. N., & Shetty, P. S. (2005). Total energy expenditure (H218O), physical activity level and milk output of lactating rural Bangladeshi tea workers and non tea workers. European Journal of Clinical Nutrition, 59(5), 632-638.

[4] Nahar, S., Mascie-Taylor, C. G. N., & Begum, H. A. (2007). Maternal anthropometry as a predictor of birth weight. Public Health Nutr., 10(9), 965-970.

[5] Callaway, L. K., Prins, J. B., Chang, A. M., & McIntyre, H. D. (2006). The prevalence and impact of overweight and obesity in an Australian obstetric population. Med J Aust., 184(2), 56-59.

[6] Begum, H. A., Mascie-Taylor, C., & Nahar, S. (2007). The impact of food supplementation on infant weight gain in rural Bangladesh; an assessment of the Bangladesh Integrated Nutritional Program (BINP). Public Health Nutr., 10(1), 49-54.

[7] Neufeld, L., Pelletier, D. L., & Haas, J. D. (1999). The timing of maternal weight gain during pregnancy and fetal growth. Am J Hum Biol., 11(5), 627-637.

[8] Mamelle, N., Cochet, V., & Claris, O. (2001). Definition of fetal growth restriction according to constitutional growth potential. Biol Neonate., 80(4), 277-285.

[9] Hemachandra, A. H. & Klebanoff, M. A. (2006) Use of serial ultrasound to identify periods of fetal growth restriction in relation to neonatal anthropometry. Am J Hum Biol., 18, 791-7.

[10] Vega, J., Sáez, G., Smith, M., Agurto, M., & Morris, N. (1993). [Risk factors for low birth weight and intrauterine growth retardation in Santiago, Chile]. Rev Med Chil., 121(10), 1210-1219.

[11] Honest, H., Bachmann, L. M., Ngai, C., Gupta, J. K., Kleijnen, J., & Khan, K. S. (2005). The accuracy of maternal anthropometry measurements as predictor for spontaneous preterm birth--a systematic review. Eur J Obstet Gynecol Reprod Biol. , 119(1), 11-20.

[12] Bonellie, S., Chalmers, J., gray, R., Greer, I., Jarvis, S. & Williams, C. (2008) Centile charts for birthweight for gestational age for Scottish singleton births. BMC Pregnancy Childbirth, 25, 8-5.

[13] Horta, B., Victora, C., Menezes, A., Halpern, R., & Barros, F. (1997). Low birthweight, preterm births and intrauterine growth retardation in relation to maternal smoking. Paediatr Perinat Epidemiol., 11(2), 140-151.

[14] Syddall, H. E., Sayer, A. A., Simmonds, S. J., Osmond, C., Cox, V., Dennison, E. M., Barker, D. J., & Cooper, C. (2005). Birth weight, infant weight gain, and cause-specific mortality: the Hertfordshire Cohort Study. Am J Epidemiol., 161(11), 1074-1080.

[15] Lapidus L, Andersson SW, Bengtsson C, Björkelund C, Rossander-Hulthén L, Lissner L.(2008). Weight and length at birth and their relationship to diabetes incidence and all-cause mortality--a 32-year follow-up of the population study of women in Gothenburg, Sweden. Prim Care Diabetes.2(3):127-133.

[16] Hui, L. L., Schooling, C. M., Leung, S. S., Mak, K. H., Ho, L. M., Lam, T. H., & Leung, G. M. (2008). Birth weight, infant growth, and childhood body mass index: Hong Kong's children of 1997 birth cohort. Arch Pediatr Adolesc Med., 162(3), 212-218.

[17] Khashan, A. S., McNamee, R., Abel, K. M., Pedersen, M. G., Webb, R. T., Kenny, L. C., Mortensen, P. B., & Baker, P. N. (2008). Reduced infant birthweight consequent upon maternal exposure to severe life events. Psychosom Med., 70(6), 688-694.

[18] Chomtho, S., Wells, J. C., Williams, J. E., Davies, P. S., Lucas, A., & Fewtrell, M. S. (2008). Infant growth and later body composition: evidence from the 4-component model. Am J Clin Nutr, 87(6), 1776-1784.

[19] Onyango, A. W., de Onis, M., Caroli, M., Shah, U., Sguassero, Y., Redondo, N., & Carroli, B. (2007). Field-testing the WHO child growth standards in four countries. J Nutr, 137(1), 149-152.

[20] Rosetta, L., & O'Quigley, J. (1990). Mortality among Serere children in Senegal. American Journal of Human Biology, 2, 719-726.

[21] de Onis M, Blössner M. (2000). Prevalence and trends of overweight among preschool children in developing countries. American Journal of Clinical Nutrition, 72:1032-1039.

[22] Fayter, D., Nixon, J., Hartley, S., Rithalia, A., Butler, G., Rudolf, M., Glasziou, P., Bland, M., Stirk, L., & Westwood, M. (2007). A systematic review of the routine monitoring of growth in children of primary school age to identify growth-related conditions. Health Technol Assess., 11(22:iii, xi-xii,), 1-163.

[23] Ogden, C.L., Carroll, M.D. and Flegal, K.M. (2008) High body mass index for age among US children and adolescents, 2003-2006. JAMA. 299, 2401-2405.

[24] Herpertz-Dahlmann, B. (2009). Adolescent eating disorders: definitions, symptomatology, epidemiology and comorbidity. Child Adolesc Psychiatr Clin N Am., 18(1), 31-47.

[25] Bearinger, L. H., Sieving, R. E., Ferguson, J., & Sharma, V. (2007). Global perspectives on the sexual and reproductive health of adolescents: patterns, prevention, and potential. Lancet., 369(9568), 1220-1231.

[26] 26.WHO-UNFPA(2006) Pregnant adolescents: delivering on global promises of hope. 29 Pages.

[27] 27. Maryam, K., & Ali, S. (2008). Pregnancy outcome in teenagers in East Sauterne of Iran. J Pak Med Assoc., 58(10), 541-544.

[28] 28. Ringback Weitoft, G., Eliasson, M., & Rosen, M. (2008). Underweight, overweight and obesity as risk factors for mortality and hospitalization. Scand J Public Health, 36(2), 169-176.

[29] 29. Davey Smith, G., Hart, C., Upton, M., Hole, D., Gillis, C., Watt, G., & Hawthorne, V. (2000). Height and risk of death among men and women: aetiological implications of associations with cardiorespiratory disease and cancer mortality. J Epidemiol Community Health.;54(2):97-103.

[30] 30. Batty, G. D., Shipley, M. J., Langenberg, C., Marmot, M. G., & Davey Smith, G. (2006). Adult height in relation to mortality from 14 cancer sites in men in London (UK): evidence from the original Whitehall study. Ann Oncol. 2006 Jan;17(1):, 17(1), 157-166.

[31] Rosetta, L. (1986). Sex differences in seasonal variations of the nutritional status of Serere adults in senegal. Ecology of Food and Nutrition, 18, 231-244.

[32] Ness-Abramof, R., & Apovian, C. M. (2008). Waist circumference measurement in clinical practice. Nutr Clin Pract., 23(4), 397-404.

[33] Garn, S. M. (1997). Body mass index in patients with unusual proportions. Am J Clin Nutr., 66(5), 1294-1295.

[34] Calza, S., Decarli, A. and Ferraroni, M. (2008) Obesity and prevalence of chronic diseases in the 1999-2000 Italian National Health Survey. BMC Public Health 8, 140-149.

[35] Romero-Corral, A., Lopez-Jimenez, F., Sierra-Johnson, J., & Somers, V. K. (2008). Differentiating between body fat and lean mass-how should we measure obesity? Nat Clin Pract Endocrinol Metab., 4(6), 322-323.

[36] Pischon, T., Boeing, H., Hoffmann, K., Bergmann, M., Schulze, M. B., Overvad, K., et al (2008). General and abdominal adiposity and risk of death in Europe. N Engl J Med., 359(20), 2105-2120.

Design and the elder phenotype: anthropometry, muscle loss and disability

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ABSTRACT

As the number of elders has increased worldwide over recent decades, the need for assessing their somatotypes, changing body shape and health have increased apace. Among these methods, old standards (height, weight, skinfolds, BMI, somatotypes) have been augmented by new techniques (fat-free mass from DEXA analyses, conicity index, CT scans). Basic anthropometric measures become more difficult as people age. Loss of muscle and bone mass that lead to postural alterations, shrinkage of skin layers and loss of subcutaneous fat, contractures, loss of cognitive function and ability to provide informed consent, physical instability, and frailty all confound assessments. Because elders are by definition a select group of survivors; they differ somatically from non-survivors. Compared to the general population, elders are leaner than other age groups, of about average height for their generation, and show lower average BMIs and skinfold measurements. Both cross-sectional and longitudinal data indicate that we lose muscle, fat, and minerals as we age. Overly ectomorphic and endomorphic somatotypes are less likely to survive to older ages, leaving those of moderate weight, height, and fatness as survivors. During old age, height shrinks due to bone loss, as posture becomes stooped; sitting height is impinged upon more than leg length. Anthropometry shows that survivors to old age are shorter, leaner, and have lower sitting heights than the middle-aged and require different design considerations. Accommodating the elderly phenotype in design interior and exterior spaces and furnishing will aid in designing universal, accessible and inclusive build environments for everyone.

1. INTRODUCTION

Worldwide, the number of elders (persons aged 65+ years) has increased over recent decades (Table 1 Crews, 2005). At the same time, expectation of life among these elders has increased (Table 1), leading to ever more numbers of old-old and oldest-old members of many populations. Many of these elders are living their additional years of life with disabilities and chronic degenerative conditions (CDCs) that impair their physical abilities and cause frailty (Crews 2005, Crews and Zavotka 2006). Older adults express phenotypes different from the young, middle-aged and young old. Frequently, they are less muscular, shorter, thinner and weaker than those who are younger. As yet, design of furniture, housing, interior and exterior spaces, bathrooms, toilets, and transportation has not accounted for the different and constantly changing somatotypes, body shapes, senses and health of elders.

In today's world, the need to include functional abilities, and frailty and the needs of elders in environmental and product design is obvious. Traditional assessments of phenotypes for design include height, weight, limb lengths, skinfolds, BMI, somatotypes. More recently developed anthropometric techniques include fat-free mass from DEXA analyses, conicity index, CT and MRI scans. But these have not yet been applied to design models. All methods become more difficult to complete with age as people change and younger cohorts with different phenotypes replace older ones, altering the dimensions of interest. The need for accessible, inclusive, and universal design for all is particularly obvious when the changing phenotypes of elders are considered (see Null and Cherry, 1996).

2. SOMATIC CHANGES WITH AGE

A number of somatic factors alter with age, foremost among these are loss of muscle (sarcopenia) and bone mass, physical instability, and frailty (Crews, 2005). Together these lead to postural alterations and shrinking height. In addition, the skin becomes thinner and less pliable as loss of subcutaneous fat occurs, confounding skinfold measurements and reducing thermoregulation. Contractures prevent completion of limb length and height measurements, while loss of cognitive function limits the ability of individuals to provide informed consent for research and treatment.

Sarcopenia, a process of senescence due to cell death and loss of functioning mitochondria, increases dramatically with age among elders (Fried et al 2001). Sarcopenia generally affects women more than men leading to increasing loss of muscle with age (Fried et al 2001). Trends for the percent of the population affected by ethnicity are similar for "White" and "Hispanic" US samples (Table 2). In addition, to muscle loss, bone matrix is lost with increasing age due to reduced osteoblastic activity relative to osteoclast activity.

Thus microfactures of bone increase with age and are less likely to be repaired leading to less mineralized and frailer bones. Additionally, both osteoporosis and osteopenia increase as bones age. Jointly, these processes lead to ever weaker bones among aging elders. At the same time cartilage becomes less elastic over time as collagen continues to crosslink with itself, reducing its elasticity and hampering skeletal mobility. Multiple joints lose their cartilaginous protective layers (knees, fingers, hips) and interverterbal disks become hard and brittle leading to back and knee pain and osteoarthritis and compression and fractures of the vertebra.

Table 1 Percent ever born surviving to selected ages in various nations (percent in the population at this age and over) life expectations at ages 70 and 80 years.

Nation	Age 70		Age 85	
	Men	Women	Men	Women
Japan	75 (9.0) 13.5y	88 (13.5) 17.7y	29 (1.3)	59 (2.3)
UK	70 (8.9) 11.9y	81 (13.5) 14.7y	21 (1.0)	39 (2.8)
USA	65 (7.4) 12.8y	79 (10.8) 15.5y	24 (0.9)	42 (2.1)
Sweden	75 (10.7) 12.8y	85 (15.3) 15.9y	27 (1.4)	47 (3.1)
Ecuador	61 (2.6) 12.1y	71 (3.3) 14.2y	** (0.2)	** (0.4)
India	41 (2.9) 10.0y	47 (3.0) 11.4y	****	****

Table source: Demographic Yearbook 1996, 1998, 2000, United Nations Department of Economic and Social Affairs, New York. Percent surviving based upon data 1992-96 India, 1994, UK and Ecuador, 1999 Sweden. Expectation of life based upon data from 1992-96 India, 1995 Ecuador, 1998 USA, 199 Japan, Sweden, and UK (** indicates data were not available for this item).

Table 2: Sarcopenia in US Elders

Age	Men		Women	
	White	Hispanic	White	Hispanic
< 70	14	18	21	25
70-74	20	20	36	35
75-80	37	27	38	40
> 80	56	54	45	45

Adapted from Fried et al 2001, J Gerontol:Biol Sci Med Sci 56:M146-156\

Bone loss, loss of cartilage, compression of joints, and the effects of gravity, produce declines in sitting height and stature as individuals age. Elders also often suffer flat feet and intervertebral disc compression, leading to additional loss of sitting height and stature. Finally, in general, shorter stature and lower body weight are associated with greater longevity – leading elders to be smaller than other adults (Samaras and Elrick 1999, Samaras et al 2004). For example, long-lived Okinawans' are generally shorter and weigh less then do other long-lived Japanes (Table 3). (Although data in Table 3 show heights and weights of centenarian Japanese women are below those of the Okinawa sample, the latter includes a large proportion aged less than 100 years).

Table: 3 Height and weight of elderly Japanese

Okinawans			All Japan	
Ages	87-104		100-105	
	Men	Women	Men	Women
Ht-cm	145.4	140.0	148.2	137.5
Wt-kg	42.8	42.2	44.1	36.7

Adapted from Samaras & Elrick 1999 Acta Med Okayama 53:149-169.

Anthropometrically elders represent a select group of survivors. They differ somatically in multiple measures from non-survivors and younger cohorts. Elders are leaner than other age groups, showing lower average BMIs and skinfold measurements. They also are generally of lower height for their generation. People generally tend to lose muscle, fat, and minerals as they age, reducing their strength, weight, and height at older ages. Thus their abilities to accomplish a number of task such as ADLS and are impaired leading to disabilities and the need for care from other and personal assistance with everyday tasks (Balloch 2005, Gerber 2005).

3. DESIGN CONSIDERATIONS

In general, both overly ectomorphic and overly endomorphic somatotypes are less likely to survive to older ages leading to statistically significant regression toward the average somotype with age.. However, sarcopenia also reduces muscle mass leading to smaller total body size and greater amounts of fat as opposed to fat-free mass. During old age, variation in body mass also is sharply reduced as smaller individuals show less mortality from heart disease and stroke (Samaras et al, 2004). Loss of muscle, fat, and bone with age not only change body habitus, they also reduce strength and flexibility. For example, many individuals aged 65+ are not able to lift 5 Kg over their own heads. Loss of strength with age is universal. Given that elders tend to be less robust in body size with lower muscle and physical abilities they require smaller furnishings than those designed for more robust middle-agers. To adequately accommodate their decreased strength, furniture may need to be of light-weight construction, drapes, pullcords and blinds need to easily movable, and housewares (e.g: pots, pans, container sizes for detergent and food) must be packaged and designed as light weight alternatives. Loss of muscle also may be accommodated with designs that limit lifting, for example in housing and aircraft. Less overhead and more under seat storage in aircraft or at waist level in homes are examples. Loss of muscle mass, height, strength and flexibility suggest that elders and others will benefit from the development and design of, lightweight and user-friendly furnishings, small container sizes, easy-open doors and windows, ramps instead of steps, open spaces, and multiple additional design features.

Survivors to old age are shorter and have lower sitting heights and leg lengths than the middle-aged. They are less able to sit with their feet on the ground in standard chairs and current chair back heights may be problematic for their reduced sitting height. Accessible/universal designs for furniture, passenger seats, and automobiles need to consider such changing somatotypes with age. Elders many not be well accommodated by today's automobile interiors with bucket seats, high riding, seat belts shoulder straps, foot-push-to-release emergency brakes, and push-out doors. All of these require either strength or a tall physique.

Multiple disabilities also often hamper elders as they age. Frailty and allostatic load both increase on average with age as do CDCs that produce disability. Disability is frequently associated with mobility restrictions and the use of canes, walkers and wheelchairs. This leads to suggestions for ramps instead of steps as already stated. In addition to these, wider doorways, ground floor access, doors that swing in both directions, more that adequate lighting with associated motion sensors and high contrast color schemes will benefit not only elders but everyone. Kitchens and bathrooms are the sites from multiple in home injuries and deaths of elders. Attention to design in these areas may greatly reduce influence rates of falls and accidents leading to greater disability and morality. Examples include contrasting color schemes for floors, walls, fixtures (e.g: toilets, tubs, sinks), and shower curtains enclosures, as well as well marked hot and cold water outlets with large Hs and Cs in bright red and blue respectively. The need for strong railings and stairways, grab bars in bathrooms and open spaces throughout homes and public spaces are well documented elsewhere(Crews 2005, Crews and Zavotka 2006). Outside the home ramps with strong railings and sides, open spaces with broad walkways that are well illuminated, along with safe distances between these and roads, traffic, and other dangers are other environmental design features that will enhance access for elders.

In general, elders show a combination of increasing frailty, disability, and sensory loss with increasing age that lead to variation in their ability to function in both natural and built environments. This is in part due to anthropometric changes in height, weight, somatotype, muscle mass, obesity, and bone structure, architecture, and mineralization. Considering these aspects of changing phenotype will to make both exterior and interior built environments more accessible and safe and wellness enhancing for all, but particularly the elderly.

4. DISCUSSION

Elders provide a common denominator for designing accessible/inclusive/universal environments and furnishings for all ages and ability levels. In particular, the frail elderly provide a model and opportunities to design our built environments in ways that accommodate all, including children and middle-aged and those adults with congenital and temporary medical disabilities, cognitive impairments, and CDCs such as Parkinson's Disease, multiple sclerosis, and senile dementia of the Alzheimer's' type. CDCs, frailty, and Disabilities affect a large proportion of the old-old (75-84 years) and the oldest-old (85+ years). The ability of elders to "age in place" by remaining in their own homes and environments will be enhanced by interior design alterations that increase their physical and mental security and limit dangers (see also Null and Cherry, 1996). This includes not only attention to their changing

somatotypes, but also other sensory losses –i.e. hearing, sight, smell. They also will experience enhanced access to exterior environments through enhanced attention to the design of outside spaces to accommodate their limited mobility and declining physical capabilities. As more of us attain elderhood the quality of design features is our built environments may aid in adding life and fulfillment to our years. From a fiscal and practical standpoint, better design will perhaps reduce our needs for health care, personal assistance, and improve our life styles.

5. REFERENCES

[1] Fried., L., P, Tangen, C., M, Waltson, J, Newman, B., A, Hirsch, C, Gottdiener, J, Seesman, T, Russel, T, Willem, J., K, Burke, G, & McBurnie, M., A.(2001). Frailty in Older Adults. , J Gerontol:Biol Sci Med Sci, 56:146-156.

[2] Samara, T., T & Elrick, H. (1999). Height, Body size, and Longevity. Acta Med Okayama. 53(4), 149-169.

[3] Balloch, S (2005). The Ageing Population: Implications for Social Services in England. Strategy for the Ageing Society: The Possibilities for Human Life Science. The Proceedings of the 13th Osaka City University International Symposium. 30 October – 1 November, 31-36.

[4] Crews, D.,E. (2005). Artificial Environments and an Aging Population: Designing for Age-Related Functional Loss. Journal of Physiological Anthropology and Applied Human Sciences. 24(1):103-09, 2005.

[5] Crews DE, & Zavotka, S. (2006) Aging, Disability, and Frailty: Implications for Universal Design. Journal of Physiological Anthropology. 25(1): 113-118.

[6] Gerber, H (2005). German Social Care System for the Elderly: The Current Issues and the Future Direction .for the Ageing Society: The Possibilities for Human Life Science. The Proceedings of the 13th Osaka City University International Symposium. 30 October – 1 November, 27-30.

[7] Null, R., L, & Cherry, K., F. (1996). Universal Design: Creative Solutions for ADA Compliance. Belmont, California, USA: Professional Publications, Inc.

[8] Samaras, T., T, Elrick, H, & Storms, L., H. (2003). Is Height Related to Longevity. Life Sciences, 72 (16), 1781-1802.

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Secular trends in anthropometry

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ABSTRACT

According to some definitions, secular trend is a process that results in a change of average size in a population from one generation to the next [1]. Manifestations of a positive secular trend include changes in growth characteristics at different stages of ontogenesis, changes in body proportions, a tendency towards early onset of sexual maturation, and also changes in adult characteristics, such as final stature, the time when it is being reached, changes in body and head proportions. There are numerous examples of "classical" secular trends for the last couple of centuries for many European countries. At the end of the 20th century the trend of increasing height has been gradually slowing or stopping in many populations, or even demonstrating the change for a negative sign. Rates of maturation also became more or less stabilized. At the same time stronger changes in body proportions have been noted, as well as changes in body fatness as reflected in a powerful increase in weight and adiposity. In Russia stature was slightly increasing during the latest decades, while such traits as weight, chest circumference and BMI were characterized with negative changes. These results show that there are important trends towards more leptosomic morphotypes in young males and females of contemporary Russia.

1. INTRODUCTION

Studies of secular changes, in spite of a huge body of work already published, still remain of considerable interest both in Russia and abroad. This is understandable because the results of interpopulation comparisons in time for different countries give different results depending on local environmental conditions.

Thus, in many European countries and in the US there is a strong tendency towards increasing weight and obesity in recent years [2, 3]. At the same time in the USA the decrease of stature was stated, quite contrary to what is observed for most countries of Europe [4, 5]. In Russia the analysis of physical development indicators was not thoroughly followed, and there were not many papers on this subject. Though there are many theories and hypothesis explaining secular changes, the most proved one connects them with socioeconomic changes in the society. In this case it is interesting to follow the changes in growth patterns in some areas of the former Soviet Union which are going on parallel to socioeconomic and political changes.

The aim of the present study is to analyze the trends in growth and sexual maturation for some populations in Russian Federation from the 1960's to the beginning of the 21st century.

2. MATERIALS AND METHODS

The analysis is based on data collected by the Institute and Museum of Anthropology, Moscow State University, for more than 40 years. It includes observations on about 10,000 Moscow children and adolescents from 8 to 17 years of age. The data were collected cross-sectionally in the 1970's, 1980's and 1990's.

In the city of Saratov (Volga-river area) about 1,400 children from 7 to 17 years of age were investigated in 2004 with the consequent comparison of their physical parameters with those from the literature. Children of Saratov were measured in 1929, 1959 and 1969. In the city of Naberezhnye Chelny (Republic of Tatarstan, Russian Federation) approximately the same number of children in the same age range of both Tatar and Russian origin was studied in 2005-2006 with the following comparison of the results to the literature.

A large number of anthropometric measurements were taken on each individual, such as height, weight, arm, leg and trunk lengths (estimated), body diameters and circumferences, skinfold thickness, head and face dimensions. Stages of secondary sexual characteristics were evaluated; data on menarcheal age were collected by status-quo and retrospective methods. In some of the populations it was also possible to evaluate the changes in hand strength, or other performance abilities.

Children were measured during or immediately after school-hours; an age group consisted of children whose age falls within the interval $\pm$ 6 months of the whole year (e.g., 7-year olds: from 6,5 to 7,5, etc.). All anthropometric measurements were taken according to standard techniques [6, 7]. Subjects were measured bare-feet, wearing only underwear. All children agreed to participate in the investigations, and corresponding protocols of consent were filled either by a subject himself or herself, or by their parents. Statistical analysis

was performed with the standard software package Statistica 6.0.

3. RESULTS AND DISCUSSION

The results for most part of the indicators are best presented for Moscow children because this population has been studied regularly throughout the 20th century. Growth curves for the main body parameters measured in 1970's, 1980's and 1990's are shown in Figures 1 and 2. As can be seen from these data, Moscow children at the end of the 20th century are becoming much narrower than their counterparts of the previous decades. They almost have not changed in stature since 1980's (in contrary to the 1970's), are the same or smaller in weight, and particularly smaller in chest circumference. This is true for both boys and girls, though in girls the changes are more expressed.

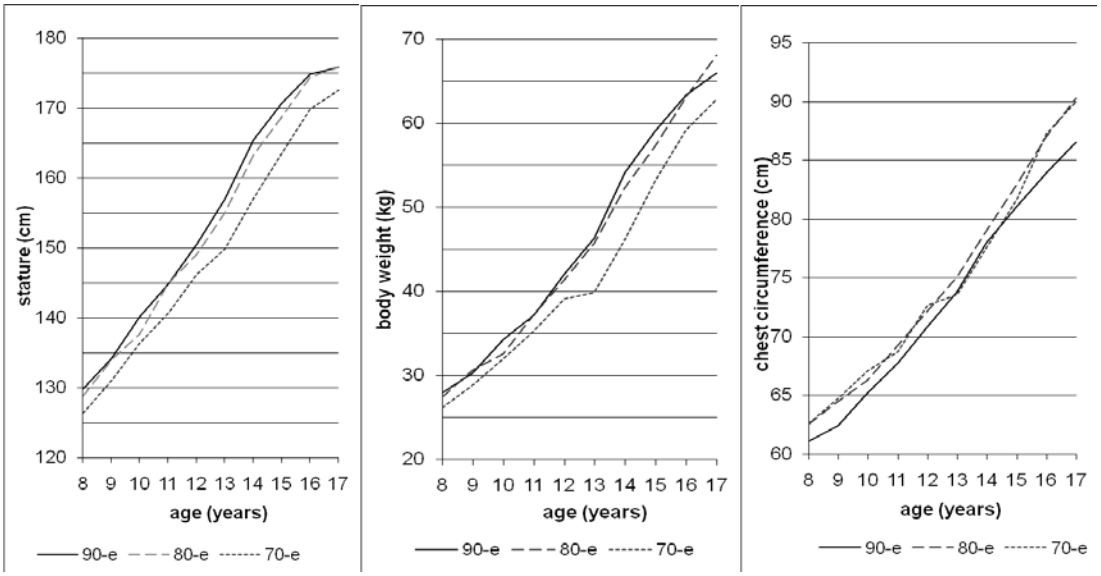

Figure 1 Secular changes of body parameters in Moscow boys

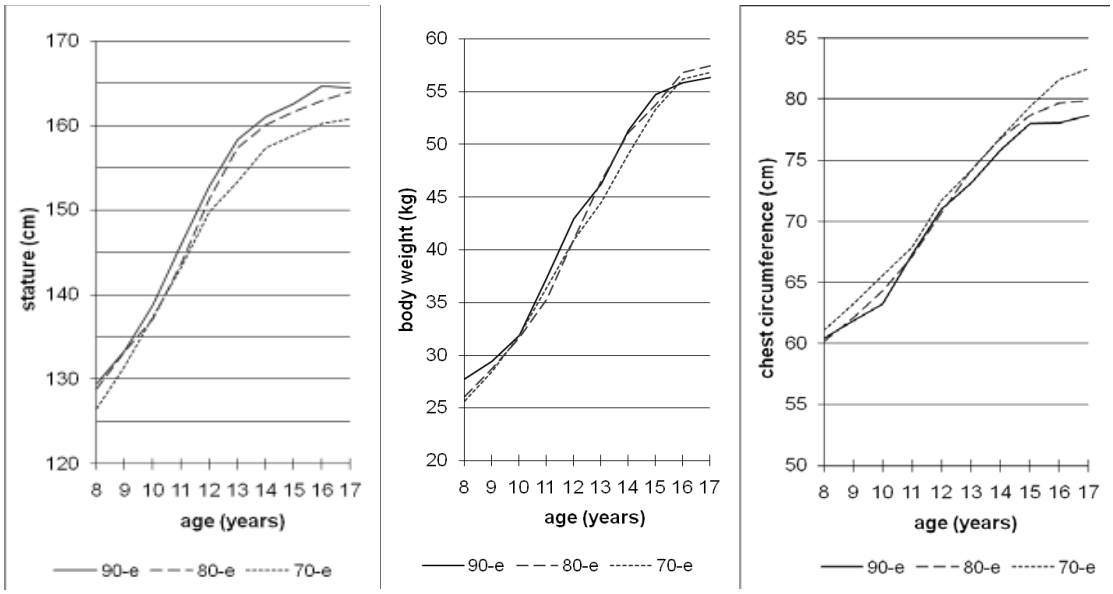

Figure 2 Secular changes of body parameters in Moscow girls

Table 1: Secular changes of cephalic and facial indices in Moscow schoolchildren

Age (years)	Cephalic index						Facial index			
	boys			girls			boys		girls	
	1940's	1960's	1990's	1940's	1960's	1990's	1960's	1990's	1960's	1990's
8	83.3	84.1	80.7	82.8	84.4	79.9	77.8	70.8	78.4	70.3
9	84.0	83.0	80.9	83.1	84.7	80.0	78.4	70.0	77.9	70.3
10	82.5	84.0	81.3	83.3	83.7	80.7	77.6	70.9	78.1	70.7
11	82.6	83.5	80.1	83.0	83.8	80.9	77.0	72.1	77.6	71.6
12	82.3	84.0	80.9	83.1	83.0	81.0	77.3	72.1	77.5	72.8
13	82.7	83.7	80.0	82.0	83.4	79.6	76.8	72.3	77.4	72.7
14	83.6	82.2	80.3	82.5	83.1	80.2	75.8	72.9	76.7	73.4
15	83.1	82.6	80.0	82.9	83.8	80.7	75.4	73.3	77.1	73.7
16	82.9	82.7	79.2	82.5	83.4	79.6	75.8	73.3	77.1	74.6
17	82.2	81.9	80.0	82.9	83.1	81.8	75.5	73.7	77.3	74.8

What is also shown here is the direction and intensity of secular changes in Russia for almost half a century. In the 1960's and 1970's there were strong positive changes in height, weight and chest circumference. Starting with the 1980's, growth in length has practically stopped and average values for weight and chest circumference are decreasing.

Stabilization of secular trend in the 1980's has been stated by many authors in different European countries [8, 9, 10, 11, 12, 13, 14, 15, 16]. But in Moscow population the halt in length growth is accompanied by decrease in weight and slower growth in width.

Chest circumference is not the only marker of this kind. Both of the chest diameters are showing these changes. On Figure 3 the same trend is shown for such an important trait as hip width. The data used for these picture are longitudinal series of measurements [17].

The trend towards more linear body build is accompanied by much less physical capacities of children and youth. Thus, the values of hand strength are becoming less than in the previous decades. For 17-year-old Moscow boys the difference is 10 kg per decade ($p<0.01$), though at younger ages (from 8 to 11) the differences are non-significant.

Besides the above-described changes, it was shown that for the last several decades some changes in the head and face morphology of Moscow schoolchildren had occurred: i.e., their heads and faces became longer and narrower (Table 1).

This trend towards debrachicephalization could be explained, to our opinion, as part of the general trend of growth in length when head length, face height and some other measurements had increased significantly ($p<.05$). At the same time decreases in some breadth measurements (head breadth, bizygomatic breadth) have also been stated [18].

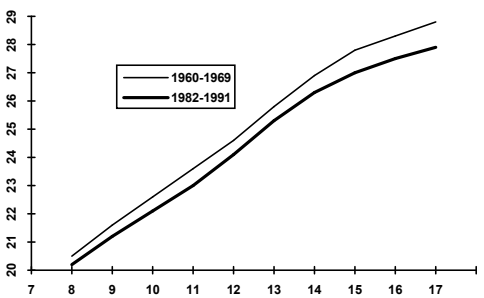

Figure 3 Growth curves of pelvic breadth (cm) in Moscow girls in two different decades (longitudinal data)

To conclude this brief overview of recent secular changes in Moscow children and adolescents let us analyze characteristics of the process of sexual maturation, with the best marker as the age of menarche. On Figure 4 archival data from Moscow Maternity Hospitals, as well as our own cross-sectional data, are presented [17]. As can be seen from the figure, the trend towards early ages was typical in the course of the 20th century (apart from Second World War years) till 1980's. The lowest age of menarche was stated in the 1970's and equaled 12.7 years. In the 1980's and 1990's a trend towards later ages is revealed: around 13.0 in both decades.

Thus, the results of the study show that for Moscow children in the last decades of the 20th century there are secular changes towards linearity, stabilization of growth in length, and later ages of sexual maturation.

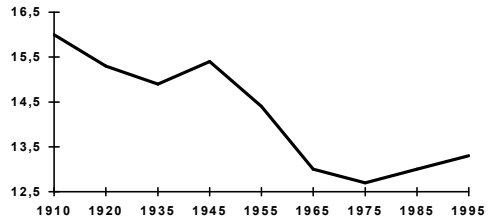

Figure 4: Changes in the age of menarche of Moscow girls in the 20th century

For other populations studied the results are very similar. Thus, for Saratov children there is even broader range of comparison: for the girls from the late 1920's to 2004, and for the boys from the late 1950's to 2004. The trends are very typical: while for the stature there was a positive increment for the last 40 years or so, for weight, chest circumference and BMI the trends are reversed, i.e. the biggest measurements are in 1969 children. The same is true for pelvic breadth in girls, which means that the same trend towards longer and narrower bodies is typical for this population as well.

In the city of Naberezhnye Chelny children of two ethnic groups – the Russians and the Tatars - have been studied. The trend towards linearity is more pronounced for the Russian group than for the Tatars but the tendency towards less muscular strength is equally characteristic for both ethnicities and sex groups. It is also noticeable that the changes towards weaker muscle force are expressed throughout the whole period of growth starting at 8-year-olds (Figure 5).

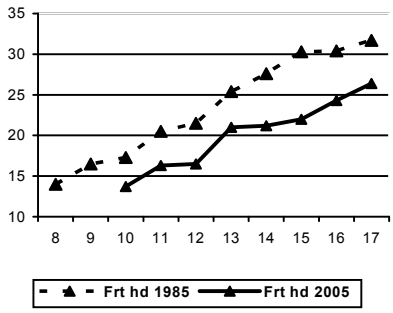

Figure 5 Secular changes in the strength of the right hand (Frt hd) for Tatar girls in 1985 and 2005.

4. CONCLUSIONS

Summarizing our results, the following conclusions may be drawn:

- The development of physical characteristics, in particular height and weight of children and adolescents, is a sensitive indicator for socio-economic conditions in which the children grow up and mature.
- Throughout most part of the 20th century, until the very last decades - in line with improvements of socio-economic conditions - the physical height and other measurements were increasing in Russian children at all age categories.
- Secular changes of children in Russia in the last decades of the 20th century and the beginning of the 21th century show a tendency towards leptosomy (*Greek*: *leptos* – narrow; *soma* – body), stabilization of growth in length, and sexual maturation, less physical strength.
- Further monitoring of physical development in children of different populations in Russia is necessary, particularly in the presence of fast social and economic changes in modern Russian society.

ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Bogin, B.A. (1999). Patterns of Human Growth. 2nd ed. Cambridge: Cambridge Univ. Press.

[2] Johnston, F.E. (2002). Social and economic influences on growth and secular trends. In: Cameron N., Ed. Human Growth and Development. Elsevier Science, 197-212.

[3] Padez, C., Fernandez, T., Mourao, I., Moreira, P., Rosado, V. (2004). Prevalence of overweight and obesity in 7-9-year-old Portuguese children: Trends in body mass index from 1970 to 2002. Am. J. Hum. Biol., 16: 670-678.

[4] Komlos, J., Baur, M. (2004). From the tallest to (one of) the fattest: the enigmatic fate of the American population in the 20th century. Econ. Hum. Biol., **2**: 57-74.

[5] Komlos J., Lauderdale B.E. (2007). The mysterious trend in American heights in the 20th century. Ann. Hum. Biol., 34: 206-215.

[6] Bounak, V.V. (1941). Anthropometry (Antropometria). Moscow: Uchpedgiz. *In Russian*

[7] Weiner, J.S., Lourie, J.A. (1969). Human Biology. A Guide to Field Methods. Oxford, Edinburgh: Blackwell Scientific Publ.

[8] Roede, M.J., van Wieringen, J.C. (1985) Growth Diagrams, 1980. Tijdschrift voor Sciale Gesondheidszorg, 63 Suppl.: 1-34.

[9] Vercauteren, M., Susanne, C. (1985). The secular trend of height and menarche in Belgium: are there any signs of a future stop? European J. Pediat., 144: 306-309.

[10] Wellens R., Malina R.M., Beunen G., Lefevre J. (1990). Age at menarche in Flemish girls: current status and secular change in the 20th century. Ann. Hum. Biol., 17: 145-152.

[11] Boldsen, J.L., Jeune, B., Bach-Rasmussen, K.L., Sevelsted, M., Vinther, E. (1993). Age at menarche among schoolgirls in Odense. Is this still increasing in Denmark? Ugeskrift f Laeger, 155: 482-484.

[12] Tryggvadottir, L., Tulinius, H., Larusdotter, M. (1994). A decline and a halt in mean age at menarche in Iceland. Ann. Hum. Biol., 21: 179-186.

[13] Liestoel, K., Rosenberg, M. (1995). Height, weight and menarcheal age of schoolgirls in Oslo: an update. Ann. Hum. Biol., 22: 199-205.

[14] Larsen, S.B., Kragstrup J. (1997). Age of Danish women at menarche and first sexual intercourse. Ugeskrift f Laeger, 159: 6676-6679.

[15] Helm, P., Groenlund L. (1998) A halt in the secular trend towards earlier menarche in Denmark. Acta Obstetr. et Gynecol. Scandinav., 77: 198-200.

[16] Bodzsar, E.B., Susanne, C., Eds. (1998). Secular Growth Changes in Europe. Budapest: Eotvos Univ. Press.

[17] Godina, E., Yampolskaya, Yu. (2004). Recent secular growth changes in Moscow schoolchildren. Anthrop Közl, 45: 51-57.

[18] Khomyakova, I.A., Godina, E.Z., Zadorozhnaya, L.V., Purundzhan, A.L. (1998). Morphological characteristics of head and face in children and adolescents of Moscow region. In: Alexeeva TI, Ed. Narody Rossii. Antropology. P. 1. Moscow: Stary Sad: 95-113. (*In Russian)*

Anthropometric Change in the U.S. Army: Implications for Design

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ABSTRACT

The U.S. Army conducted a major anthropometric survey in 1988 in which 132 standard dimensions were measured on nearly 9000 active duty personnel. That data base has subsequently been used to design everything from uniforms and protective equipment to tanks, helicopters and parachute harnesses. Since that time, the Army's force structure has changed to more fully utilize Army Reserve and Army National Guard personnel to supplement active duty forces in virtually all operations. That change and others prompted an investigation to determine whether the 1988 data base was still representative of today's fighting force. In a pilot study conducted in 2007, we measured 3462 soldiers (2811 males and 651 females) from all three components for 25 dimensions, of which 10 are reported here. We conducted two types of statistical comparisons on male soldiers: 1) active duty 1988 vs. active duty 2007 and 2) inter-component. We also examined 95th and 99th percentile values, as they are widely used in product and workspace design. Active duty comparisons – 1988 males to 2007 males – showed statistically significant differences in 9 of 10 dimensions, using independent sample T-tests. There were also differences in height and weight by component. The examination of extreme percentile values showed 6 of the 10 dimensions at either the 95th or 99th percentiles were changed substantially enough to affect product design. We have recommended that the Army consider a full-scale survey to update its data base.

1. INTRODUCTION

Anthropometric data are used in the design of many military products, from clothing and personal protective equipment to major systems, such as tanks, helicopters and other aircraft. The U.S. Army completed its last major anthropometric survey of active duty personnel in 1988 (ANSUR) [1] and has designed equipment using those data for the past 20 years. Since that time, several changes have raised a question about whether that data base should be updated in order to create appropriate designs for the next 20 years. Specifically, a change in strategy called the Total Force Concept has resulted in continuing use of the Army Reserve and the Army National Guard. These two reserve components, where members spend part of their time in the civilian sector, and part of their time in the active military, were not measured in 1988, and they are anthropometrically unknown. Second, there is an obesity epidemic in the United States and elsewhere in the developed world, and it is not known whether this epidemic has had an effect on the anthropometric characteristics of the Army. In this context, the U.S. Army Natick Soldier Research, Development and Engineering Center decided to conduct a pilot anthropometric survey of current active duty, Army Reserve and Army National Guard. The two questions addressed by the pilot study are: 1) has the active duty Army experienced anthropometric change in the last 20 years; and 2) are the active duty, Army Reserve and Army National Guard components anthropometrically different from each other.

2. METHODS

2.1 Sampling Plan

The United States has broad ethnic diversity in the general population, and in its armed forces. As racial and ethnic origin is strongly associated with some anthropometric characteristics, we included race and ethnicity categories in our sampling plan. The race and ethnicity goals were set to reflect the current demographic profile of the three components. The overall goals were proportionately divided between the two posts where data collection was planned: Ft. McCoy Wisconsin for Reserve and National Guard soldiers and Ft. Hood for Active Duty soldiers. Similarly, since many anthropometric characteristics change with individual age, we monitored the participant age distribution during data collection to ensure adequate representation of all age groups, although we did not have specific sampling targets for each race/age cell.

Sample size was determined through a power analysis using waist circumference – the most variable of the dimensions to be measured – where 90% detection of mean differences 12mm or larger between Active and Reserve/National Guard components was the goal for two-sided .05 level tests. This goal was achieved for male

soldiers. However, as female soldiers represent only 15.5% of the Army, it was impossible to measure enough females at only two sites to achieve the same level of statistical power. Instead a minimum 15.5% proportional target was the goal set for female participation, and every effort was made to measure more. That said, the study included only 651 females, rendering statistical power for female tests between components well below 50% for most dimensions. For this reason, only males are reported in this paper.

2.2 Dimension Selection

In the previous Army survey (ANSUR 1988) we recorded data on 132 measured dimensions plus three-dimensional coordinates on head and face landmarks. That number of dimensions was not necessary to answer the questions posed in this pilot study. Instead, we selected 25 dimensions which included those important for tariffing combat items, as well as for basic design of the next generation of protective equipment and workspaces. Most areas of the body are represented by one or two dimensions. For this paper, we report on 10 of the most critical dimensions.

2.3 Data Collection

Data were collected at Ft. McCoy, WI between June and October of 2006 and at Ft. Hood between February and June of 2007. After completing a brief demographic questionnaire, participants changed into running shorts (males) or running shorts and sports bras (females). Body landmarks (typically skeletal points) were marked on the skin. After marking, each participant was measured for the 25 dimensions. Data were entered into a laptop computer operating data entry and editing software [2]. When an unusual value was detected, a signal was given and the dimension remeasured. Following the completion of all data collection, data were edited again to identify any remaining usual values. Potentially erroneous values were compared against hand-written data sheets, and either corrected or deleted from the data set.

3. RESULTS AND ANALYSIS

Table 1 shows the final pilot study sample size. Note that the target for females was exceeded. However, given their greater statistical power, we focus on male results for the remainder of this paper.

Table 1: Pilot Study Sample

Component	Male	Female
Regular Army	1475	287
Army Reserve	771	579
National Guard	565	118
Total	2811	651

Table 2 shows the racial and ethnic distribution of the males in the sample. It also demonstrates the broad diversity within the U.S. military.

Table 2: ANSUR 2 Pilot Study Males – Racial/Ethnic Distribution

Race Group/ Ethnicity	Active	Ethnicity	Reserve	Ethnicity	National Guard	Ethnicity
White	870		469		369	
Black	224		129		74	
Hispanic	156		91		84	
Mexican		80		29		14
Puerto Rican		46		40		65
Other Hispanic		30		22		5
Asian/PI	42		28*		9	
Filipino		14		10		2
Samoan		3		2		0
Korean		6		3		2
Vietnamese		1		6		0
Other Asian		5		5		4
Other PI		13		1		1
Amerind	12		3		0	
Mixed/Other	171		51		29	
Totals	1,475		771		565	

*One Asian/PI missing ethnicity data

3.1 Sample weighting

The individual Army units that participated in this study were not necessarily demographically representative of the total Army on which the sampling goals were based. Further, participation in the study was voluntary, in the sense that any individual soldier had the right to withdraw at any time. Therefore the final racial/ethnic sampling cells and age group targets were not filled exactly. To correct for this, the final sample was statistically weighted to match total-Army demographic distributions. For the purpose of weighting, we created sample cells based on age and race and calculated age/race cell proportions from 2007 Total Army Census Data provided by the Defense Manpower Data Center. Sample weights are calculated for each age and race sampling cell as the ratio of target population proportion over sample population proportion, or $W = pT/pS$. Subject weights are greater than 1 when the sample proportion of the pilot study cell

is smaller than the comparable population proportion of the total Army; weights are smaller than 1 when the sample proportion of the pilot study cell is larger than the comparable population proportion of the total Army. All statistical results are based on the statistically weighted data.

3.2 Change from 1988 to 2007

Figure 1 shows ellipses that enclose 90% of the population. By comparing the two ellipses, it is possible to see the change in height and weight between the 1987-1988 data set (ANSUR) and the current pilot study data set (ANSUR 2 Pilot).

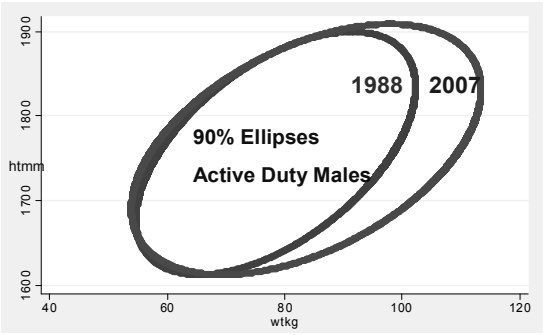

Figure 1: 90% Accommodation Ellipses - Active Duty Males, 1988 and 2007

Note that the lower end of the height and weight distribution is largely unchanged. The upper end of the height distribution is slightly higher in the pilot study, but the upper end of the weight distribution is substantially larger in the more recent data. The mean values have increased by 4.4 mm in height, and 5.2 kg in weight. This overall body size difference suggests that designs of protective clothing, equipment, and workspaces based on the older anthropometric data may not be optimal for the current user population.

3.3 Differences in Components

Figure 2 shows that there are some differences, in overall body height and weight, between the components. The Army Reserve is closest to the active duty, where it is only 4.6 mm shorter on average, and 1.9 kg heavier. The National Guard is the most different from the active duty, being on average 11.5mm shorter and 3.2 kg heavier. While many of these differences can be accounted for by the demographic differences between components, the conclusion can be drawn that the groups are different enough that protective clothing, equipment, and workspace design should not be done on Active Duty only, and simply migrated to the other components. Instead, all three components should be included in a U.S. Army design data base.

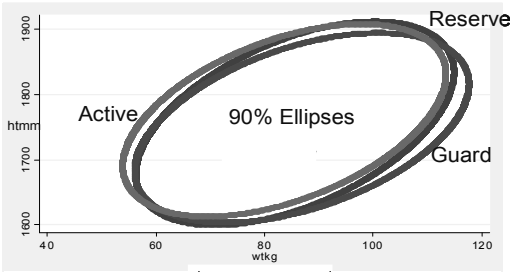

Figure 2: 90% Accommodation Ellipses- Active Duty Males, Army Reserve Males and Army National Guard Males

3.4 Creation of an Interim Data Base

Given the differences between components, and the changes in the last 20 years, a decision was made to create an interim data base, using data from the ANSUR 2 pilot study, which would combine data from all three components. We used statistical weighting, as described above, to ensure that the data base is representative of both the demographic composition and the component composition of the total Army. The question remains, though, whether the differences seen in height and weight, both among components and in the change over time, would have practical significance in the design of actual products and military systems. To address this issue, we compared some specific dimensions that are often used in the design of clothing, protective equipment, and major military systems such as aircraft. We compared the interim data base derived from the ANSUR 2 pilot study – statistically weighted to represent the current total Army – against the 1988 ANSUR data base, which is the data we would use if newer data were not available.

4. DATA BASE COMPARISON: PRACTICAL CONSIDERATIONS

Table 3 shows the comparison of means and standard deviations between 1988 ANSUR values (labeled "1988") and the current pilot study values (labeled "2007"). Some of the 2007 means are smaller, especially in the dimensions that are composed of largely skeletal elements. These include Crotch Height and Knee Height Sitting. Other dimensions, especially those that have a significantly fleshy component, are larger; these include major circumferences (buttock, waist, and chest), and weight. All dimensions except stature are statistically significantly different (T-test for independent samples) at the 0.0001 level. It is also striking that all of the standard deviations show an increase. Clearly some of the increases

are very small—less than a millimeter—and obviously inconsequential, but some are substantial. The largest increases in standard deviation are in the major circumferences and weight. This suggests that not only is the Army getting larger in some key dimensions, but also more variable.

Increased variability has a direct impact on clothing tariffs and design guidelines, which are typically not based on the population means, but on extreme values, both large and small. In general (although not always), design value ranges are taken from 1st or 5th percentile female values to 95th or 99th percentile male values. We continue our focus on the male values, and therefore the upper end of the design range.

Table 4 shows the male 95th and 99th percentile values for both the older (ANSUR) data base and the data base from the pilot study. The 95th percentile values are substantially larger in the current population for at least three dimensions that are critical in clothing design, sizing and tariffing and one in workspace layout. These are Buttock Circumference, larger by more than 7 cm, Chest Circumference, larger by 9.7 cm and Waist Circumference, larger by over 11 cm. Bideltoid Breadth, a dimension useful in clothing as well as workspace design, is larger at the 95th percentile by just over 2 cm. The unifying theme among all these dimensions is Weight, whose 95th percentile value is 11.9 kg larger than the ANSUR 95th percentile. Weight is not generally a design dimension alone (although it is used in the design of safety harnesses and similar equipment), but as seen here, it influences many other dimensions that have a direct impact on design.

The 99th percentile values are typically used in safety-critical applications. All of those dimensions noted above are now substantially larger at the 99th percentile as well. In addition, hip breadth, sitting, which is critical in many aircraft ejection situations, has increased 2.5 cm. The 99th percentile weight, critical in determining crashworthiness of aircraft seating and the strength of parachute harnesses and other body support apparatuses has increased more than 15 kg.

(Table 3 and 4 on page 50)

5. SUMMARY AND CONCLUSION

Potential anthropometric changes in the U.S. Army prompted a pilot study to determine: 1) differences in body size of active duty soldiers between the time of the last anthropometric survey in 1988 and the present; and 2) differences among the 3 components of the Army. The identification of differences in either case would suggest changes in the data base from which Army clothing, protective equipment and military systems are designed. A pilot study was designed and carried out to answer both questions.

We found that there were important changes in height and weight between the active duty Army of today and the active duty Army measured 20 years ago. While the lower end of the 90 percent accommodation range was not substantially changed, the upper end changed markedly, reflecting increased variation in the population. Similarly, we found meaningful differences in height and weight between Army components, although these can be largely explained by the significant demographic differences between the components. Still, this latter discovery indicated that future design of Army systems should be conducted on a data base that reflects the total Army, rather than just the active duty component.

The conclusions from the pilot study lead to the recommendation that a new anthropometric survey, a full study of all the components, should be undertaken, and a new updated data base created. Properly sampled, such a data base should serve the Army's anthropometric design needs for the next generation of soldiers.

Table 3: Male Means and Standard Deviations of 1988 and Interim 2007 Data Bases – Selected Dimensions

(values in cm and kg)

	MEAN			STANDARD DEVIATION		
DIMENSION	**1988**	**2007**	**DELTA**	**1988**	**2007**	**DELTA**
	N=1774	N=2809 to 2811		N=1774	N=2809 to 2811	
Bideltoid Breadth	49.2	50.2	1.0*	2.59	3.26	0.67
Buttock Circumference	98.4	102.9	4.5*	6.22	7.48	1.26
Chest Circumference	99.1	104.8	5.7*	6.91	9.27	2.36
Crotch Height	83.7	82.8	-1.0*	4.63	5.00	0.38
Hip Breadth, Sitting	36.7	37.3	0.6*	2.52	3.04	0.53
Knee Height, Sitting	55.9	55.6	-0.3*	2.79	2.83	0.04
Sitting Height	91.4	91.9	0.5*	3.56	3.66	0.11
Stature	175.6	175.6	0.0	6.68	6.99	0.31
Waist Circumference	86.2	94.0	7.8*	8.64	11.10	2.46
Weight	78.5	85.2	6.7*	11.11	14.01	2.90

* Statistically significant at 0.0001

Table 4: Male 95th and 99th Percentiles of 1988 and Interim 2007 Data Bases – Selected Dimensions

(values in cm and kg)

	95th %ile			99th %ile		
DIMENSION	**1988**	**2007**	**DELTA**	**1988**	**2007**	**DELTA**
	N=1774	N=2809 to 2811		N=1774	N=2809 to 2811	
Bideltoid Breadth	53.5	55.7	2.2	55.2	59.0	3.8
Buttock Circumference	108.7	116.0	7.3	113.5	121.7	8.2
Chest Circumference	111.5	121.2	9.7	116.9	127.5	10.6
Crotch Height	91.6	91.2	-0.4	94.7	94.8	0.1
Hip Breadth, Sitting	41.2	42.7	1.5	43.0	45.5	2.5
Knee Height, Sitting	60.5	60.4	-0.1	62.4	62.6	0.2
Sitting Height	97.2	98.0	0.8	99.1	100.6	1.5
Stature	186.8	187.2	0.4	191.0	193.0	2
Waist Circumference	101.5	112.6	11.1	108.4	121.3	12.9
Weight	98.8	110.7	11.9	107.8	123.4	15.6

6. REFERENCES

[1] Gordon C.C., Bradtmiller B., Churchill T., Clauser C.E., McConville J.T., Tebbetts I., and Walker R.A. (1989). *1988 Anthropometric Survey of US Army Personnel: Methods and Summary Statistics*. Natick, MA: US Army Natick Research, Development and Engineering Center. Report Number NATICK/TR-89-044.

[2] Churchill T.D., Bradtmiller B., and Gordon C.C. (1988) *Computer Software Used in U.S. Army Anthropometric Survey 1987-1988.* Natick, MA: US Army Natick Research, Development and Engineering Center. Report Number NATICK/TR-88/045.

Elite to high street footwear: the role of anthropometric data

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ABSTRACT

Rapid manufacturing has been revolutionary allowing the production of personalised design components for products like footwear to the final customer. Foot shape plays an important role in the development of injuries in runners, therefore any footwear should take into account an individuals mass, foot shape and other measures to provide unique support, balance, and comfort to the wearer. Despite the obvious potential in footwear products, it is not known how best to measure feet in this context nor even whether a personalised shoe can positively affect comfort, performance and prevent risk from injury. A challenge for anthropometry is the collection of detailed anthropometric measurements of the foot which can then be used to specify the design of personalised footwear. A pilot study is being conducted to assess the feasibility of personalising the design of insoles for running shoes. Rear striker, recreational runners (n=6) were selected to take part in the study. They were 18-64 years old, had no reported musculoskeletal pain or injury in the last 12 months. If they had any known lower limb abnormality they were excluded from the study. The plantar surface of the feet were scanned and detailed anthropometric measurements taken. Using these data insoles for a running shoe were rapid manufactured for comparison with the standard running shoe. Participants then returned to the laboratory to be fitted with a running shoe under two experimental conditions (personalised and standard footwear). For each experimental condition, the footwear was evaluated in terms of comfort (visual analogue scales), performance (running economy on a treadmill) and injury risk (knee and ankle torque, ground reaction force and plantar pressure distribution). This paper will present and discuss the detailed methodology for this research.

1. INTRODUCTION

Rapid manufacturing (RM) is potentially revolutionary in developing high performance, personalised footwear. This technology can benefit not only elite runners but any individual who wishes to be more active, such as recreational joggers and older individuals. As RM works without any tooling, it can significantly reduce unit costs as products can be produced near the location where they will be used, minimising transportation and stock space (Hopkinson & Dickens, 2001). RM can also allow the production of unique elements allowing industry to provide personalised components.

Foot shape plays an important role in the development of many types of injury (James et al, 1978, McKenzie et al, 1985, Cowan et al, 1993). According to Williams III et al (2001a), low arched runners tend to have greater eversion/tibial internal rotation ratio, in comparison with high arch runners, which leads to more soft tissue and knee injuries. High arch runners tend to have more bony foot and ankle injuries (William III, 2001b). Moreover, the high arch foot tends to experience more ankle sprains because of higher lateral loading, peak pressure and supination of the foot (Morag & Cavenagh, 1999, William III, 2001b). In terms of comfort, low arch individuals prefer harder insoles whereas those with a high arch tend to choose softer ones.

Personalising footwear can decrease the magnitude of impact force, provide stability and traction for different terrains, protect the foot and provide comfort to maintain aerobic work over a longer period. Generally, when an individual purchases footwear, only two measurements are taken (length and width), but there are other measures considered crucial. These include, metatasophalangeal joint girth, heel height, arch height and toe box space (Cheng & Perng, 1999, Witana et al, 2004).

Studies have indicated that 'fit' is the most important component of footwear not only because it is strongly correlated to comfort, but because it is speculated to be linked to injury and damage prevention (Cheng & Perng, 1999; Wunderlich & Cavanagh, 2001; Luximon et al, 2003). Too little or too much space in a shoe can be perceived as tight or loose respectively (Witana et al, 2004). Too tight a shoe will compress tissues leading to discomfort whereas too loose a shoe will lead to tissue friction because of the slippage between the foot and the shoe both causing blisters (Cheskin et al, 1987).

Despite the obvious potential in footwear products, it is not known how best to measure feet in this context nor even whether a personalised shoe can positively affect comfort, performance and prevent risk from injury. A challenge for anthropometry is the collection of detailed anthropometric measurements of the foot which can then be used to specify the design of personalised footwear. This paper describes the design of a pilot study to determine the most effective methods of measuring comfort, performance and injury risk.

2. METHOD

2.1 Aims and objectives

The main aim of the research is to develop high performance personalised footwear for high street individuals using rapid manufacturing (RM). It is expected that this research will ultimately benefit a diverse sample of people, for example, the over 65s, people with conditions effecting foot shape such as diabetes and arthritis and anyone who wishes to be more active.

In order to start to define the measurement techniques for specifying such personalised footwear, a pilot study was conducted. The main objectives of this study were:

1. To develop and refine anthropometric measurement techniques for specifying personalised footwear.
2. To evaluate the effectiveness of these techniques in terms of measuring footwear comfort, performance and injury risk.
3. To understand the rapid manufacturing process in this context e.g. time required, reliability of hardware and software, materials available.

2.2 Sampling

For this pilot study, it was decided to focus on participants who have some experience of wearing sports footwear, therefore a convenience sample of six recreational runners was recruited. Inclusion criteria were: 18-65 years old, some experience running (at least 5km/week), that they were rear foot strikers, no reported musculoskeletal pain or injury in the last 6 months, and had not used an orthosis in the last 12 months.

It was intended to use leg length discrepancy and Quadriceps angle to judge whether to exclude participants who might be at risk of injury, but early pilot trials revealed that the bony landmarks needed are difficult to find leading to inaccuracies. For example, leg length is measured as the distance between the anterior superior iliac spine to the inferior edge of the medial malleolus.

2.3 Procedure

A repeated measures experimental design was used, with a balanced presentation of two conditions: insole (shoe + personalised insole) and control (standard shoe). The time of day was standardised for each participant to take part in the experimental sessions. It was proposed that the two conditions would be compared in terms of comfort, performance and injury risks. Ethical clearance was received for the study in July 2008.

Table 1: Anthropometric measurements based on Williams & McClay (2000)

Measurement	Description
Navicular height	Floor to the most anterior-inferior portion of the navicular
Dorsum height	Dorsum height at 50% foot length
Foot length	The most posterior portion of the calcaneous to the end of the longest toe
Truncated foot length	The most posterior portion of the calcaneous to the centre of the 1st MTP

Initial contact was made with participants with a brief explanation of the study. The research can be divided into four clear stages which are described as follows:

In session 1 (40 minutes) detailed anthropometric measurements were taken, following Williams & McClay (2000) to classify the foot type, and measurements based on Hawes & Sovak (1994), to capture dimensional aspects of the foot (Tables 1 and 2). Following guidelines by Williams & McClay (2000), dorsum height was measured under two weight bearing conditions (10% and 90% of weight bearing). The other foot 'height' measures described in Table 2 were measured with 50% weight bearing on each foot. Scales and a block were used to facilitate these (Figure 1). Arch ratio, arch index and relative arch deformation were calculated from these measures following Williams and McClay (2000). In addition, a 3D scan was made of the plantar surface of both feet in an non weight bearing position (Figure 2). Stature and weight were also captured for each participant.

Table 2: Anthropometric measurements based on Hawes & Sovak (1994)

Measurement	Description
Foot length (1st digit)	The most posterior portion of the calcaneous to the end of the 1st digit (hallux)
Foot length (2nd digit)	The most posterior portion of the calcaneous to the end of the 2nd digit
Foot length (5th digit)	The most posterior portion of the calcaneous to the end of the 5th digit
Metatarse fibulare length	The most posterior portion of the calcaneous to the centre of the 5th MPJ
Hallux height	Floor to the superior surface of the hallux
MPJ height	Floor to the superior point of the 1st joint
Navicular height	Floor to the most anterior-inferior portion of the navicular
Foot breadth	Between the metatarsale tibiale and fibulare
Heel breadth	Measured with compression to the bony surface and the point of maximum heel width
MPJ girth	Measured encompassing the metatarsale tibiale and fibulare.
Mid arch girth	Measured in the frontal plane passing through the dorsum
Heel girth	Measured encompassing the dorsum and the point of distal heel contact on the standing surface

Figure 1: The set up showing scales and a block to facilitate taking anthropometric measurements

Scanned data were first 'cleaned' and then personalised insoles were manufactured from Polymide using a selective laser sintering RP process technology. These were to be fitted to the trainers for the experimental sessions.

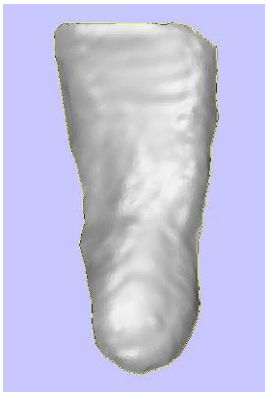

Figure 2: Example of scanned plantar surface of the foot

In the second session (75 minutes), in-shoe plantar pressure (Nm/cm^2) was measured to quantify pressure distribution by placing a sensor inside each shoe. Participants were asked to run at the same speed as a normal training session, 5 x 10 metres under each condition whilst planter pressure distribution was recorded. To estimate running economy (performance), after a short warm up in their own trainers, participants ran for 4 minutes on a treadmill to reach a steady rate and then 2 minutes for analysis of gases (under each condition). The lower the volume of oxygen consumed per unit of body mass per time, the more efficient the runner and thus a better performance. The treadmill was set at 1% gradient as this has been shown in the literature as most accurately reflecting the energy 'cost' of outdoor running. At least a five minute break was given between runs. Foot comfort in each condition was measured using a visual analogue scale (the most comfortable imaginable to not comfortable at all). Six regions of the foot were assessed, the heel, midfoot, forefoot, fit, arch height, and overall (Mundermann et al, 2002). Thermal comfort was measured using a 7 point (from hot to cold) Predicted Mean Vote scale.

In session 3 (75 minutes), participants were first asked to do five practise 'runs' in their own trainers for 10 metres to gain experience of landing on a force platform. This would allow the capture of vertical peak ground reaction force (N); high values of peak vertical impact forces are positively related to increased injury risk (Mundermann et al, 2004; Yung-Hui and Wei-Hsien, 2005). The footwear (under both conditions) were fitted (in a balanced order) and reflective markers placed on landmarks on the lower limb for tracking 3D movement. Participants were asked to run 5 x 10 metres under each condition, while the kinematic data were collected

using the Vicon Motion System (Oxford, UK). The collection of ground reaction force and kinematic data were synchronised. The kinematic data were used to assess knee and ankle torques (Nm). High values of peak joint torques are associated with increased risk of injury. Finally, the body landmarks were removed and participants performed another running economy test under each condition following the procedures described in the previous session. Ideally session 3 would take place 2 days after the previous session.

3. SUMMARY

Data collection started in October 2008. Detailed anthropometric data have been taken for all six participants, personalised insoles have been manufactured and the trials have commenced. It is likely that the findings of this pilot study will be published in 2009. This pilot work is the pre-cursor for a longitudinal study involving a broader sample of the population and which will commence in 2009.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Hopkinson, N. & Dickens, P. (2001). Rapid prototyping for direct manufacture. *Rapid Prototyping Journal, 7*(4), 197-202.

[2] James, S.L., Bates, B.T. & Osternig, L.R. (1978). Injuries to runners. *The American Journal of Sports Medicine, 6*(2), 40-50.

[3] McKenzie, D.C., Clement, D.B. & Taunton, J.E. (1985). Running shoes, orthotics and injuries. *Sports Medicine, 2*, 334-347.

[4] Cowan, D.N., Jones, B.H. & Robinson, J.R. (1993). Foot morphologic characteristics and risk of exercise-related injury. *Archives of Family Medicine, 2,* 773-777.

[5] Williams III, D.S., McClay, I.S., Hamil, J. & Buchanan, T.S. (2001a). Lower extremity kinetic differences in runners with high and low arches. *Journal of Applied Biomechanics, 17*, 153-163.

[6] Williams III, D.S., McClay, I.S., & Hamil, J. (2001b). Arch structure and injury patterns in runners. *Clinical Biomechanics, 16*, 341-347.

[7] Morag, E. & Cavanagh, P.R. (1999). Structural and functional predictors of regional peak pressures under the foot during walking. *Journal of Biomechanics, 32*, 359-370.

[8] Cheng, F.T. & Perng, D.B. (1999). A systematic approach for developing a foot size information system for shoe last design. *International Journal of Industrial Ergonomics, 25*, 171-185.

[9] Witana, C.P., Feng, J. & Goonetilleke, R.S. (2004). Dimensional differences for evaluating the quality of footwear fit. *Ergonomics, 47*(12), 1301-1317.

[10] Wunderlich, R.E. & Cavenagh, P.R. (2001). Gender differences in adult foot shape: implications for shoe design. *Medicine and Science in Sports and Exercise, 33*(4), 605-611.

[11] Luximon, A., Goonetilleke, R.S. & Tsui, K.L. (2003). Footwear fit categorisation. In: M.M.Tseng & F.T. Piller (Eds). *The Customer Centric Enterprise: Advances in Mass Customisation and Personalisation*, (pp. 491-499). New York: Springer.

[12] Cheskin, M.P., Sherkin, K.L. & Bates, B.T. (1987*) The Complete Handbook of Athletic Footwear.* New York: Fairchild Publications.

[13] Williams, D.S. & McClay, I.S. (2000). Measurements used to characterise the foot and the medial longitudinal arch: reliability and validity. *Physical Therapy, 80*(9), 864-871.

[14] Hawes, M.R. & Sovak, D. (1994). Quantitative morphology of the human foot in a North American population. *Ergonomics, 37*(7), 1213-1226.

[15] Mundermann, A., Nigg, B.M., Stefanyshyn, D.J. & Humble, R.N. (2002). Development of a reliable method to assess footwear comfort during running. *Gait and Posture, 16*, 38-45.

[16] Mundermann, A., Nigg, B.M., Humble, R.N. & Stefanyshyn, D.J. (2004). Consistent immediate effects of foot orthoses on comfort and lower extremity kinematics, kinetics and muscle activity. *Journal of Applied Biomechanics, 20*, 71-84.

[17] Yung-Hui, L. & Wei-Hsien, H. (2005). Effects of shoe inserts and heel height on foot pressure, impact force and perceived comfort during walking. *Applied Ergonomics, 36*, 355-362.

A preliminary Study on the Development of an Office Chair for Able-bodied Users Based on a Foot-driven Wheelchair for Individuals with Cerebral Palsy

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ABSTRACT

The concept of Physiological polytypism proposes that humans consist of multiple sub-groups some with very small populations whose physiological functions differ significantly from those of others. Cerebral palsy is one of these sub-groups. The Active-Chair Foot is a foot-driven wheelchair for individuals with cerebral palsy. The wheelchair's seating surface consists of a sling seat with elastic belts to support the pelvis and efficient propulsion is assisted by an attached spring. The purpose of the wheelchair's adaptation is to ensure proper head-neck alignment based on the Active Balanced Seating method. The mechanism of the Active-Chair Foot was applied to new office chairs currently under development. The prototype, code-named the U60E, has a backrest with a particular kind of flexible material, and a seat with slits to support the torso. A specially adjusted spring is fitted to assist reclining movement. To examine the function of the prototype U60E, we compared it with a common office chair (referred to below as chair A) with a somewhat stiff backrest and a non-slitted seat. Two able-bodied adolescents participated in the experiment, in which the rear view was scanned using a 3D measurement system. Pressure patterns were measured, and motion was analyzed kinematically using a motion capture system. The pressure distribution and 3D digital modeling indicated that the U60E offered a higher level of support for the pelvis and thorax than chair A. Motion analysis indicated that reclining movement was triggered by kicking the ball of the foot. The trajectory movement area of the backrest in the U60E was lower than that of chair A, meaning that the dorsal surface of the pelvis was supported constantly throughout the reclining movement in the U60E. We speculate that the rhythmical shift of the body's center of gravity assisted by a flexible backrest, slitted seat and adjusted spring is a common requirement in the development of office chair design based on the Active balanced Seating.

1. INTRODUCTION

Cerebral palsy is the term for a range of non-progressive syndromes of posture and motor impairment resulting from insult to the developing central nervous system (Koman et al., 2004). People with cerebral palsy who have not developed trunk control have difficulty eating, speaking, moving about and executing the regular activities of daily living (Barks, 2004). Such individuals are often prescribed special seating systems to improve posture (Neilson et al, 2001). We have developed three wheelchairs with original mechanisms (named the Active-Chair Hand, the Active-Chair Foot and the Seating Buggy) for individuals with cerebral palsy. We have also developed methods of fitting of wheelchairs, including techniques for these three original models. The name given to the wheelchair's seating arrangement is *Active Balanced Seating* (ABS) - a standard that has succeeded in clinical environments for those with cerebral palsy. However, further scientific investigation of ABS is still required. We found the scientific term *technological adaptability* in the field of physiological anthropology to be a most appropriate concept in the development of the scientific aspects of ABS. To investigate appropriate seating systems, information relating to actual human beings is needed, and the effects of the ABS method on the physical capabilities of the disabled are the focus of this investigation. The ABS concept for wheelchair seating may be further developed by the sapiential term *technological adaptability* which includes the concepts of whole body coordination and functional potentiality (Sato, 2005). It is clear that adaptability cannot be separated from potentiality. In fact a well-fitted wheelchair based on ABS improves the overall body coordination of individuals with cerebral palsy, bringing efficient performance with coordinated movement of the four limbs, torso and head-neck. This may indicate stimulation of the latent potential for physiological ability in disabled people. The concept of physiological polytypism holds that the human population includes multiple normal physiological types, and various differences between individuals

can be measured through a number of physiological procedures (Sato, 2005). We hypothesized that the disabled population, including those with cerebral palsy, can be included among these multiple physiological types. Each sub-type population element would be adapted to the environment with the most appropriate industrial product based on the physiological polytypism (Inoue et al., 2006; Hatta et al., 2007). We assume that such industrial products consists of common and specific elements based on physiological measurements, meaning that finding the common elements in a certain kind of industrial product on the basis of this physiological measurement is the most important challenge. If the ABS wheelchair seating method for individuals with cerebral palsy offers complete response to a certain physiological measurements, then it can be applied to various other segments of the population, including average individuals. With this in mind, we applied the mechanism of the Active-Chair Foot for the individuals with cerebral palsy to our new office chair code-named the U60. The purpose of this preliminary article is to introduce the developmental process of the U60 office chair based on the ABS method and to present the results of evaluating the interaction between humans and the chair's new functions.

2. METHODS

2.1 The concept of the Active Balanced Seating

We propose the ABS as a method of adjusting of the wheelchair seating with higher regard for balance, and hypothesize that well-balanced posture attained through ABS might compensate for muscle weakness. ABS is a configuration that provides adequate support for balance against the gravity in the disabled individuals who cannot sit well. Under the ABS concept, those with severe sitting disabilities can sit with a well-balanced posture in a properly adjusted seating system from the view point of the ABS concept. The key point of the goal of ABS is a well-balanced posture with proper head-neck alignment.

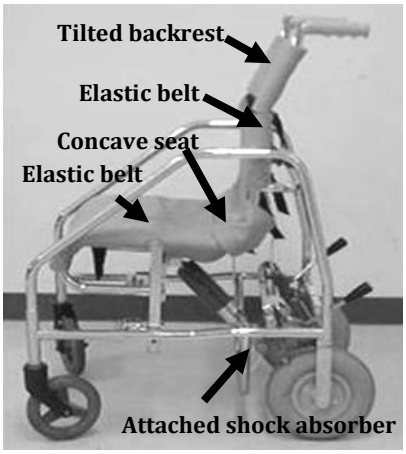

Figure 1: The Active Chair-Foot

2.2 The mechanisms of the Active Chair-Foot

We have developed an original wheelchair named the Active Chair-Foot based on ABS in 1993 (Fig.1).

The chair was developed for the individuals with athetoid cerebral palsy most of whom cannot use their upper extremities because of their athetoid movements or spasticity. In contrast to their palsied upper extremities, many such individuals have a higher level of control in the lower extremities. The Active Chair-Foot is a foot-driven wheelchair for those who can not use their upper extremities. The chair's seating surface consists of a tension-adjustable sling seat with elastic belts to support the pelvis. The upper belt supports the dorsal part of the pelvis while the lower belt supports the bottom of the pelvis. The sacrum spine and the ischial tuberosity of the pelvis are supported by the tension-adjustable sling seat with lenience. The upper part of the backrest pipe is tilted backward of the 28 degrees, and its curve follows the natural curvature of the spine. The body is constantly supported closely by the support surface. The seat is sustained by the attached shock absorber, and rotates around the axis which is under the seat. The reactive force of the shock absorber was adjusted in linear fashion, and its extension speed was controlled at 0.3m/sec. The principle of leverage was applied to the seat's movement, and the fulcrum of the under-seat lever is placed close to the greater trochanter. The body is buoyed in a neutral position with proper head-neck alignment. The seat rotates in an antero-posterior direction following the movement of the individual – a mechanism that contributes to efficient propulsion (Fig.2).

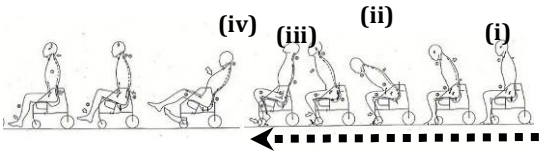

Figure 2: Propulsion of the Active Chair-Foot

The movement of the lower extremities cannot be separated from the movement of the pelvis and the torso as it can in walking. In the Active Chair-Foot, the mobility of the pelvis and torso are assisted by the chair's mechanism. The lack of restriction on the mobility of the pelvis and torso contributes to the mobility of the lower extremities. The driving pattern is outlined below. (i) The chair is propelled forward by pulling the ball of the foot back while inclining the upper body forward, thus moving the center of gravity forward. (ii) After the body reaches its foremost position, the user moves it back immediately to recover the balance, and body regains a neutral position. (iii) After the body reaches the midline, backward swinging is induced by the backward inclination of the seat controlled by the contraction of the attached shock absorber. In the meantime, the wheelchair is propelled forward by the force of inertia. (iv) After the body reaches its rearmost position, the user begins to swing forward assisted by the resilience of the shock absorber.

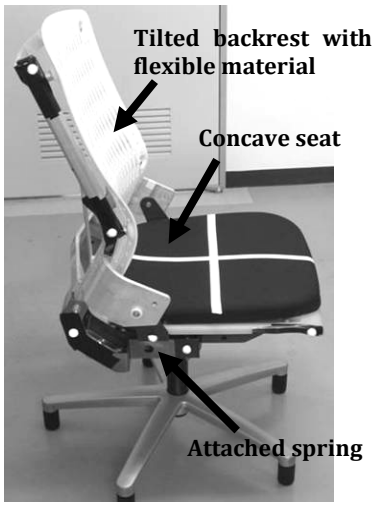

Figure3: The U60E (Codename)

2.3 Newly Developed prototype Office Chair (code-named the U60)

The method used to achieve a well-balanced posture and the efficient driving movement for individuals with cerebral palsy might also benefit able-bodied individuals.

We therefore applied the important mechanisms of the Active Chair-Foot to the new U60 prototype office. The U60E is a prototype of the fifth version of the U60, and has a tilted backrest with a particular kind of flexible material, a seat featuring a concave back part with slits, and attached springs (Fig.3). The body weight of the U60E user is counterbalanced in a neutral position by the concave seat, the tilted backrest and the reactive force of the attached springs. The U60E is of course not a wheelchair, so it is not designed for propulsion like the Active Chair-Foot, but the mechanism of the Active Chair-Foot was applied to its reclining movement.

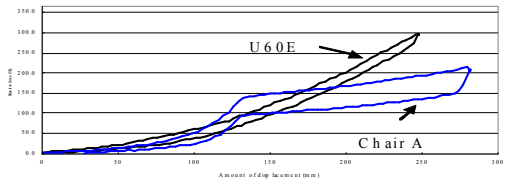

Figure 4: Reactive force and amount of displacement

The attached torsion coil spring and the tension spring were adjusted to generate reactive force in a linear fashion same as the Active Chair-Foot when the backrest was inclined backward and forward (Fig.4).

2.4 Protocol

To examine the function of the U60E, we compared it to a typical office chair (referred to as *chair A*) with a somewhat hard backrest and a non-slitted seat. The U60E's backrest has a higher flexibility than that of chair A. Two able-bodied students participated in the experiment - one was a male with a height of 182cm and a weight of 67kg (Subject 1), and the other was a female with a height of 147cm and a weight of 48kg (Subject 2). Subjects were fully informed about the procedures, risks, and benefits of the study, and written consent was obtained before the study. The back view was scanned using the TRiDY (JFE Techno-Research Corporation) 3D shape measurement system to convert the real seating support surface of the U60E into usable digital models. The scanned data was exported in DXF format and imported into RapidForm2006. An accurate 3D model of the backrest's rear view was

constructed through data processing, and the shape of the backrest was traced as a line. Movements were recorded kinematically using a Frame-Dias II (DKH Inc.) 3D motion analysis system with a four-camera configuration. Reflective markers were placed along the subject's bodies at the following points: 1) temple, 2) auricle, 3) mental protuberance, 4) acromion, 5) iliac crest, 6) anterior superior iliac spine, 7) proximal edge of the greater trochanter, 8) knee joint, 9) ankle joint, and 10) metatarsal bone (the lateral side of the ball of the foot). Sampling of the kinematic data was started a few seconds before reclining movement, and was performed 10 times for each participant. The pressure pattern of the body was measured using the FSA (Verg Inc.), which consists of two pressure-sensing mats, an interface module and computer software. The pressure-sensing mats, which have 256 individual sensors, were used to measure the pressure distribution on the seat and backrest respectively. The FSA system is a tool to evaluate interface pressure between a person and a supporting surface. The center point of pressure was calculated from the measured pressure distribution. The subjects were instructed to 1) sit with 0-degree, 10-degree and 20-degree inclinations of the backrest and 2) execute reclining movements ten times with a free backrest.

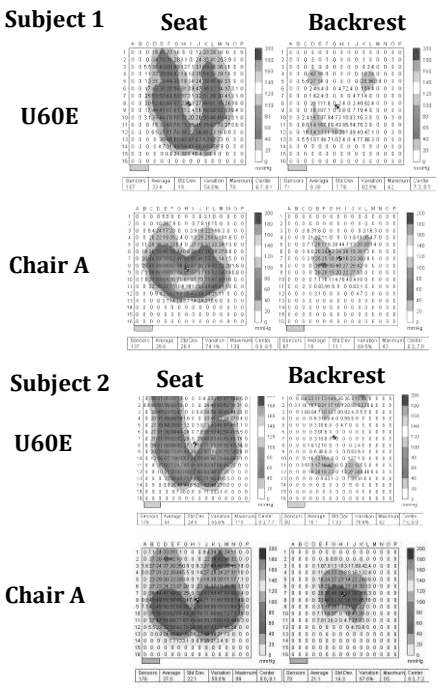

Figure 5: FSA pressure patterns

3. RESULTS

The pressure distribution on the seat indicated that the pelvis was positioned further back on the seat in the U60E compared with chair A (Fig. 5). The higher pressure zone is confined to the pelvis area in chair A.

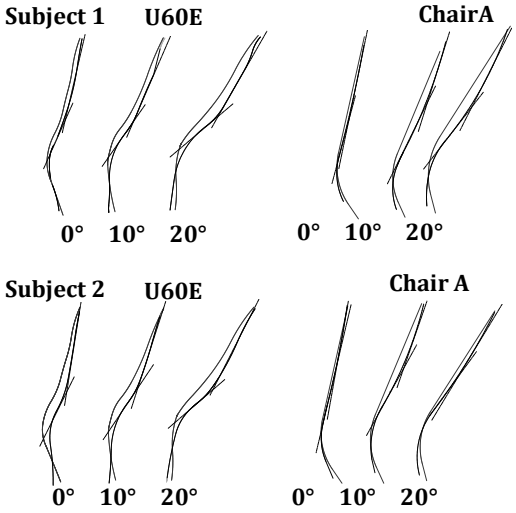

Figure 6: The backrest in the Saggital plane

However the pressure distribution of the U60E's seat extended to the thigh area. The pressure pattern of the backrest indicated that the pelvis area was better supported by the U60E than by chair A. The thorax area was also released more by the U60E than by chair A (Fig5). Conversely pressure on the thorax area in chair A was higher than in the U60E, indicating that the subject was pushed forward in the area of backward inclination to a supine position. The curve of the thorax was traced in the sagittal plane (Fig 6). Its natural curve was found to be more absorbed by the backrest of the U60E than by that of chair A. The line of the thorax area was divided into two parts, and its upper portion with the U60E was found to be relatively further back than with chair A. The lower part of the thorax line with the U60E was emerged more apparently than with chair A. We called it as *Third Angle of Thorax* (Nishimura and Hatta, 2008; Hatta and Nishimura, 2008). A thorax shape with the natural curvature of the spine seemed to be better supported by the Third Angle of Thorax line with the U60E. A linear form was approximated for the each part of the line, and the angle of the linear form was then measured with reference to the perpendicular. The angle of the upper part of the thorax was no different between chair A and the U60E (Table 1). However, the angle of the Third Angle in the U60E

was larger than that with chair A, indicating that the backrest of the U60E does not push the thorax or support it from below. The results for the shape of the backrest are not inconsistent with its pressure pattern.

Table 1: The angle of the approximated line of the thorax

Subject 1						
	0°		10°		20°	
	U60E	Chair A	U60E	Chair A	U60E	Chair A
Upper side	7.9	10.1	17.8	19	27.1	31.2
Third Angle	23.4	13.3	33.8	28.8	49.3	36.5
Subject 2						
	0°		10°		20°	
	U60E	Chair A	U60E	Chair A	U60E	Chair A
Upper side	13.1	11.7	23.5	17.4	29.8	26.9
Third Angle	24.2	14.1	34.9	26.2	49.8	36.2

The trajectory of the center point of pressure reflected the shift in the body's center of gravity with the reclining movement of the support surface (Fig. 7). The arrowheads indicate the center of the seat in the anterio-posterior direction or the backrest in the up-down direction respectively. The data for Subject 1 in the U60E indicates some mechanical errors caused by lose of contact with the backrest. However, no any problem is found from simple visual analysis of the pattern. The pressure center point of the seat in the pelvis area moved widely in the U60E according to the reclining movement. The trajectory movement area of the backrest in the U60E was lower than that of chair A, and the dorsal surface of the pelvis was supported constantly throughout the reclining movement with the U60E. Conversely, the pelvis area was not supported well in chair A. Pushing movements on the floor with the ball of the foot occurred regularly with the U60E (Fig 8), while the same regular movements of the ball of the foot were not observed in chair A. Additionally, the vertical element of the position change depth in the ball of the foot with the U60E was longer than that of chair A.

4. DISCUSSION

The back part of the U60E's concave seat allows the pelvis to sink about 1 inch into the seat. This concavity may contribute to the posterior location of the pelvis, the extension of pressure distribution to the thigh area and the support for the dorsal surface of the pelvis by the backrest (Fig.5). Due to the supported of the pelvis by the backrest of the U60E, the backward inclination of the pelvis (which was commonly-noted in the sitting position) was reduced. It was reported that the back part of the seat without ischial support increases lumbar lordosis, and may be a better option for people sitting for prolonged periods (Lin et al., 2006).

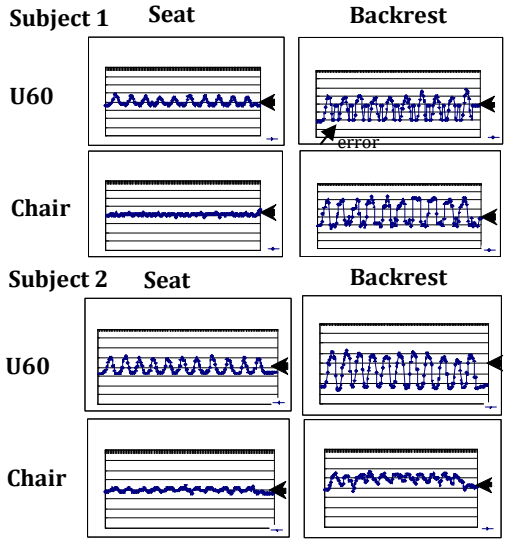

Figure7: The trajectory of the pressure center point

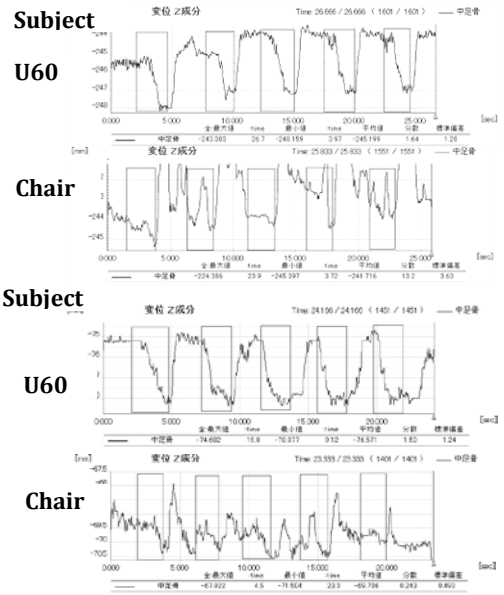

Figure 8: The pushing movements of the ball of the foot

The neutral position of the pelvis itself may establish as a stable base for the appropriate alignment of the torso. The Third Angle with the U60E was emerged more apparently than with chair A (Fig.6), indicating that the upper body seemed to be supported well by the lower part of the backrest's thorax area with the U60E. The natural backward inclination of the thorax may be absorbed by the higher flexibility of the backrest in the U60E. It was suggested that proper head-neck alignment as a key concept of ABS may also be achieved by the appropriate alignment of the torso depending on the stability of the pelvis. Conversely, the more planar and somewhat hard backrest of chair A pushed the natural curve of the thorax forward. It was suggested that the alignment of the torso in chair A might deteriorate with the backward tilting of the pelvis (Fig. 5). The trajectory of the pressure center point during reclining reflected the interaction between the support surface movement and the body movement. The dorsal area of the pelvis was supported constantly by the backrest of the U60E (Fig. 7). The constantly supported pelvis during reclining movement in the U60E may establish itself as a stable base for the appropriate alignment of the torso and head-neck. The appropriate alignment of the upper body with a well-balanced posture was possible with the U60E, and the pressure pattern for the bottom of the pelvis indicated that it rotated constantly around the fulcrum of the seat. The fulcrum shaft of the U60E was near the greater trochanter, and the center of gravity fell through the greater trochanter in the standing position. It can therefore be speculated that the center of the gravity fell near the greater trochanter in a properly aligned sitting position. This positional relationship between the fulcrum and the center of gravity meant that backward reclining movement was easy to initiate. The backward reclining of the body in the U60E is triggered by pushing movements from the ball of the foot. The force thus generated acts on the pelvis via the ankle and the knee. The backward inclination of the backrest can be brought about by the shifting the center of gravity, through pushing movements from the ball of the foot. Due to the compensation of the muscle strength from the shift in the center of gravity in the U60E, the force generated by the ball of the foot may be small. The backward shift in the center of gravity caused by the backward-rotated pelvis was followed by contraction of the attached springs. The attached springs were adjusted to generate a reactive force in a linear fashion (Fig. 4). Forward movements, in the U60E might be assisted by the resilience of the spring. It was suggested that the reclining movements of the body were assisted more by the mechanisms included in the U60E than by chair A. The backward reclining of the body in chair A can be performed by the pushing movement of the thorax against the backrest. This was a commonly observed pattern. The mechanisms of the Active Chair-Foot for individuals with cerebral palsy were successfully applied to the newly developed U60E prototype office chair for able bodied users. However, the mechanisms adopted here were not fully examined from the view point of physiological measurement. So the further investigation is therefore needed to confirm the mechanism of the U60E as a common element for the development of a chair based on the scientific aspect of ABS.

5. REFERENCES

[1] Koman L A, Smith B P, Shilt J S (2004) Cerebral palsy. Lancet 363: 1619–31

[2] Barks L (2004) Therapeutic positioning, wheelchair seating, and pulmonary function of children with cerebral palsy: A research synthesis. Rehabil Nurs 29: 146-153

[3]Neilson A R, Bardsley G I, Rowley D I, Hogg J, Malek M, Morrison G C, Kirkwood C A(2001) Measuring the effects of seating on people with profound and multiple disabilities-A Preliminary study. J Rehabil Res Dev 38: 201-214

[4]Sato M (2005) The development of conceptual framework in Physiological Anthropology. J Physiol Anthropol Appl Human Sci 24(4): 289–295.

[5]Inoue K, Hatta T, Nishimura S (2006) An approach to wheelchair design by using the physiological polymorphism of users with cerebral palsy. The 8th International Congress of Physiological Antholopology Abstracts Book: 3.

[6]Hatta T, Nishimura S, Inoue K, Yamanaka M, Maki M, Kobayashi N, Kishigami H, Sato M (2007) Evaluating the Relationships between the Postural Adaptation of Patients with Profound Cerebral Palsy and the Configuration of the Seating Buggy's Seating Support Surface. *J Physiol Anthropol 26(2): 217–224.*

[7] Nishimura S, Hatta T (2008) Evaluating the characteristics of a new wheelchair's adjustable back-support. 24th International Seating Symposium Syllabus. 271.

[8] Hatta T, Nishimura S (2008) Characteristics of the Seating Buggy's Seating Surface developed for severely disabled people. 24th International Seating Symposium Syllabus. 272.

[9] *Lin F, Parthasarathy S, Taylor S J., Pucci D, Hendrix R W, Makhsous M(*2006) Effect of Different Sitting Postures on Lung Capacity, Expiratory Flow, and Lumbar Lordosis. Arch Phys Med Rehabil 87:504-509

Physiological effects of earthquake motion on humans

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ABSTRACT

In terms of human casualties, the big earthquake that hit the Chuetsu region of Niigata prefecture in October 2004 was Japan's most devastating quake since the Hyogo-ken Nanbu earthquake of 1995. Of the resulting 12 fatalities, one of the common cause of death (30.8%) was the "shock" associated the quake. Although a small number of deaths due to shock occurred in previous earthquakes, shock accounted for only 0.03% of deaths in quakes before 1960, and no more than 4.58% of deaths in quakes after 1960. When viewed in this context, the number of fatalities due to shock in the Chuetsu earthquake is striking.

We investigated the possible correlation between some kind of factors and earthquake fatalities attributed to shock. We focused particular attention on the duration of the earthquake and used this parameter to identify the existence of a natural period over which the effects of a quake – particularly fear – affect humans, and if such a period does exist, how long people are sensitive.

In this study, we used physiological indicators (blood pressure, heart rate) to assess the effect that earthquakes have on humans during the period of earthquake motion. The aim of the study was to clarify the factors underlying the fatalities due to shock at the time of earthquake occurrence. In addition, we examined the correspondence between subjective "experience" indicators and objective physiological indicators. The results showed that the peak values of blood pressure, heart rate, and "experience" indicators all occurred at earthquake with a duration of 0.4 seconds.

This value corroborates the findings of previous research which showed that humans are most receptive to the effects of earthquake motion when the duration of the earthquake motion is comparatively short (0.5 seconds). We were thus able to demonstrate that earthquake duration and the sensation of earthquake motion produces feelings of fear in humans.

1. INTRODUCTION

40 people lost their lives by the 2004 mid Niigata earthquake in Japan. Among of them, the cause of death of 12 fatalities was the "shock" (Table 1). The ratio of dead according to "shock" was very high, 30.8%. Therefore, we want to clarify the reason why so many people dead by "shock" in the earthquake. We investigated the possible correlation between some kind of factors and earthquake fatalities attributed to shock. We focused particular attention on the duration of the earthquake and used this parameter to identify the existence of a natural period over which the effects of a quake –particularly fear- affect humans.

2. CASUALTIES IN PREVIOUS QUAKES

A look at the records of previous earthquakes shows that 25% of all fatalities caused by, for example, the 1964 Niigata earthquake, are attributed to shock. However, what is not clear from the results is whether these fatalities occurred during the period of earthquake motion. Aside from the 1978 off the coast of Miyagi prefecture earthquake and in which approximately 10.7% of fatalities were due to shock, the proportion of fatalities in previous earthquakes was very low (<5%). Although the total number of fatalities due to shock in Hyogo-ken Nanbu earthquake of 1995 was as high as 16, this number represents only a tiny proportion of the more than 6,400 people who lost their lives in the quake. Generally, the further away one is from the hypocenter of an earthquake, the longer the motion associated with the earthquake will last. Consequently, even for the same earthquake, the measurements of this "predominance period" depend on where the measurement is made. For this reason, in cases where multiple data were available, we used the locations closest to the hypocenter(Table 2).

Below, we examine the correlation between subject attributes and weather conditions against fatalities due to shock. As can be seen in Fig.1, the majority of the people who died due to shock in the Niigata-ken Chuetsu earthquake(Mid Niigata earthquake) were elderly. This is probably because elderly people are more likely to suffer from afflictions that can result in sudden death,

such as myocardial or cerebral infarction (heart attacks or strokes) and also pulmonary infarction. Of the 12 fatalities in the Niigata-ken

Table 1: Comparison with the cause of death due to earthquakes

Cause	Before 1960 (%)	After 1960 (%)	Mid Niigata
Building damage	89.68	4.30	25.60
Slop collapse	0.54	31.52	15.40
Fall & turnover objects	0.39	8.02	2.60
Fire	6.54	1.15	0
Shock	0.03	4.58	30.80
Tsunami	2.50	48.71	0
Others	0.31	1.43	25.60%

Chuetsu earthquake, five (42%) were due to myocardial or cerebral infractions. In these cases, it is likely that the fear due to shock resulted in an instantaneous elevation of blood pressure. Although slightly more males than females died due to shock, the difference is too small for there to be any useful conclusion regarding gender (as shown in Figure.1).

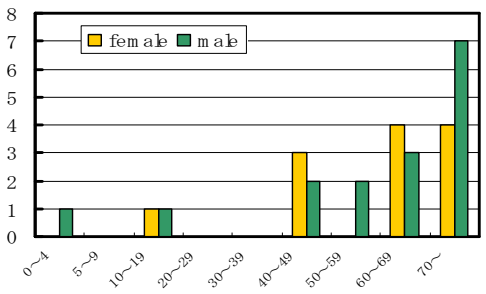

Figure 1: Fatalities due to shock in recent earthquakes

Table 3 lists shows prevailing weather data at the time of occurrence of Various earthquakes for earthquakes exhibiting the highest proportion of fatalities due to shock. Although no rainfall occurred at the time of occurrence of all earthquakes, there is no conclusive correlation between the lack of rainfall and the occurrence of fatalities due to shock.

Table. 2: Death rate due to shock in previous earthquakes

EQ.	Year	Inten-sity	Period (sec)	Dead (%)
Nobi	1891	5	1.3	0
Anegawa	1909	6	-	0
Kanto	1923	6	-	0
Kawachi	1936	5	1.0	0
Oga	1939	5	-	0
Mikawa	1945	5	-	0
Nankai	1946	-	2.3	0.4
Tokachoki	1952	5	0.7-1.0	3.2
Niigata	1964	5	-	25.0
Tokachioki	1968	-	2.0	4.2
Izuooshima	1974	5	0.28	0
Miyagioi	1978	-	0.9-1.0	11.0
Urakawaoki	1982	6	Long	0
Hokkaidou	1993	5	0.22	2.1
Hyogoken	1995	7	0.38	0.4

Table 3: Weather data at the time of occurrence of earthquakes after 1960

EQ.	Death rate by shock	Precipi-tation (mm)	Tempe r-ature (℃)	Hum -idity (%)	Wind speed (m/s)
Chuetsu	30.8	0	10.9	50	0
Niigata	25.0	0	20.4	79	3.8
Miyagi	10.7	0	19.2	87	3.1
Tokachi	4.2	0	7.3	75	3.0
Hokkaido	2.1	0	18.9	85	1.0
Hyougoken	0.35	0	3.4	54	4.6
Izuooshima	0	0	10.6	68	2.5

3. EXPERIMENT

We employment the vibration simulator of the Department of Civil Engineering at Tokyo Metropolitan University to assess four different levels of seismic intensity (S.I.)(Japan Meteorological Agency): 300 gal (slightly below S.I.=6), 400 gal (slightly above S.I.=6), 500 gal (S.I.=7), and 600 gal. In addition, we used vibrations with periods from 0.1 ton 1.0 seconds, which includes the range of the seismic disturbance associated with the Niigata-ken Chuetsu earthquake (0.2 to 0.7 sec.), as measured at places like Ojiya City (0.7 sec.) and Tokamachi City (0.25 sec.). However, due to limitations of the vibration simulator, in practice the maximum excitation period was 0.8 seconds at 400 gal and

0.7 seconds at 500 gal and 600gal. We used one voluntary student for the subject. As physiological indicators we used heart rate and blood pressure. In addition to these objective physiological indicators, we administered a questionnaire to the subject (21-year young male) in which we asked him to rate, on a scale of 1 to 5, the sensation of fear he sensed immediately after experiencing the earthquake-like vibration. Out of safety considerations, this test was performed with the subject seated, rather than standing, on the vibration table. Furthermore, handrails were fitted to the apparatus using the boltholes of the vibration table to help prevent subject from falling off the table. In addition, the subject was required to wear safety helmets for the duration of the experiment.

Photo 1: Situation of experiment

4. CONCLUSIONS

In this study, we used physiological indicators (blood pressure, heart rate) to assess the effect that earthquakes have on humans during the period of earthquake motion. The aim of the study was to clarify the factors underlying the fatalities due to shock at the time of earthquake occurrence. In addition, we examined the correspondence between subjective "experience" indicators and objective physiological indicators. The results showed that the peak values of blood pressure, heart rate, and "experience" indicators all occurred at earthquakes with a duration of 0.4 seconds (as shown in Figure.2).

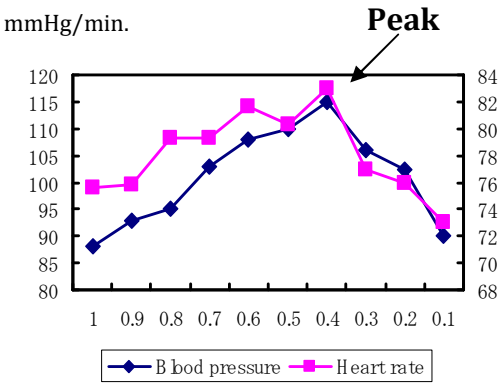

Figure 2: Relationship between blood pressure, heart rate and period of vibration

This value corroborates the findings of previous research which showed that humans are most receptive to the effects of earthquake motion when the duration of the earthquake motion is comparatively short (0.5 seconds). We were thus able to demonstrate that earthquake duration and the sensation of earthquake motion produces feelings of fear in humans(as shown in figure 3).

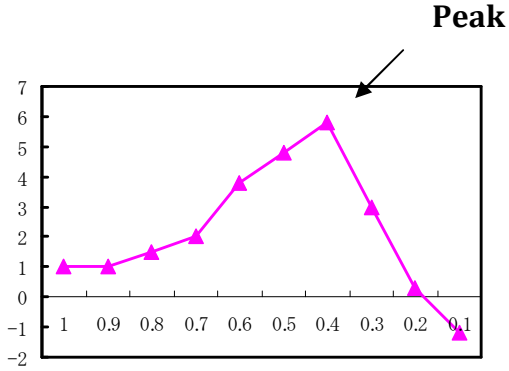

Figure 3: Relationship between the sensation of fear and period of vibration

5. REFERENCES

[1] National Research Institute for Earth Science and Disaster Prevention (2005). The Earthquake at Off Miyagi Prefecture , (hinet.bosai.go.jp/topics/miyagi050816/head_j.html)

Utility of Somatotype Rating as a Measure of Body Composition in Japanese College Track and Field Athletes

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ABSTRACT

Although estimating body composition is important in assessing the performance potential for athletes, a method for athletes having highly developed physical performance level has not been established. The purpose of this study was to investigate the utility of somatotyping for measuring body composition in Japanese college athletes. Anthropometric measurements were made in 73 male and 33 female college track and field athletes (18-21 yr). We measured skinfold thickness (SF), girth measurements and bioelectric impedance (BI). Somatotype was determined according to the Heath-Carter anthropometric method. Fat mass index (FMI; kg·m-2) and fat-free mass index (FFMI; kg·m-2) were calculated from body compositions that were estimated by both SF and BI (FMI-SF, FMI-BI, FFMI-SF and FFMI-BI, respectively), and were analyzed in relation with anthropometric somatotype data. High correlations above r=0.80 were obtained from the relations of each component of somatotype and body composition as follows: endomorphy vs. FMI-SF in males (r=0.97) and vs. FMI (both -SF and -BI) in females (r=0.96 and r=0.90); mesomorphy vs. FFMI (both -SF and -BI) in males (r=0.85 and r=0.86) and in females (r=0.81 and r=0.80), and ectomorphy vs. FFMI (both -SF and -BI) in males (r=-0.81 and r=-0.83) and vs. FMI (both -SF and -BI) in females (r=-0.83 and r=-0.83). Multiple regression analysis depending on the three components of somatotype for prediction equations of body composition in male and female athletes were carried out, and a high accuracy (r=0.73-0.99) was found in this multiple analysis. These findings in the present study suggest that anthropometric somatotype rating would be useful as a measure of body composition in Japanese college athletes.

1. INTRODUCTION

The athlete's body is characterized by having less fat, which is important to attain high athletic performance. Therefore, estimating body composition is necessary to assess the performance potential of athletes. Most generally used model is a classic two-component model, which divide whole body mass into fat mass (FM) and fat-free mass (FFM) [1]. There are many estimation methods based on the model, but easy and correct method could be useful in a field of sports training. Although, Skinfold thickness (SF) or bioelectrical impedance (BI) used widely is easy and convenient methods, predictive equation of these methods made from non-athlete would be inapplicable to athletes with highly-developed physical performance level. Consequently, a method for athletes has not yet been established. Meanwhile, somatotyping has been used for the assessment of athlete's physiques, which is easy and correct measure [2]. If somatotype is greatly related to body composition, anthropometric somatotyping would be useful for measuring body composition. Slaughter and Lohman showed significant relationship between somatotype and body composition in college-aged women [3]. However, there is no study for athletes. Accordingly, we investigated the relationship between somatotype and body compositions by both SF and BI in Japanese college track and field athletes. The purpose of this study was to assess the utility of somatotyping for measuring body composition in athletes.

2. METHODS

2.1 Subjects

Seventy-three male and thirty-three female Japanese college track and field athletes (18-21 yr) including sprinters, distance runners, jumpers and throwers participated in this study.

2.2 Measurements

All anthropometric measurements were performed according to standard techniques by trained investigator. Height, weight, five skinfold thicknesses (SF; biceps, triceps, subscapular, suprailiac and medial calf), two girths (flexed upper arm and calf), and two biepicondylar breadths (humerus and femur) were measured on the right side of the body. Bioelectrical impedance (BI) for assessing body composition was measured according to the procedure described by Komiya and Masuda [4] and using a generator (TP-202K, Toyo Physical, Fukuoka, Japan). The characteristics of subjects were shown in Table 1.

2.3 Body compositions

Estimating body composition was made by both SF described by Lohman [5] and BI. In the present study, Fat mass index (FMI; kg·m^{-2}) and fat-free mass index (FFMI; kg·m^{-2}), standardized fat mass and fat-free mass by height, were employed as body composition index, which are useful for comparison of the body composition between subjects having different height [6][7]. FMI and FFMI were calculated from body compositions that were estimated by SF and BI (FMI-SF, FMI-BI, FFMI-SF and FFMI-BI, respectively).

2.4 Somatotype

Somatotype was determined according to the Heath-Carter anthropometric method [2]. Endomorphy, mesomorphy and ectomorphy score, i.e. three somatotype components, were calculated from anthropometric measurements.

2.5 Statistics

All data are presented as mean±SD. A pearson's correlation coefficient was employed to test the relationship between two variables. Multiple regression analysis depending on the three components of somatotype for prediction equations of body composition were carried out. Statistical significance was accepted at $p<0.05$.

Table 1: Characteristics of Japanese college athletes

	Male (n=73)	Female (n=33)
Height (cm)	172.5±6.1	162.5±5.6
Weight (kg)	65.8±7.9	59.0±13.5
BMI (kg·m^{-2})	22.1±2.4	22.2±3.9
FMI-SF kg·m^{-2})	3.5±1.4	5.8±3.1
FFMI-SF kg·m^{-2})	18.6±1.4	16.4±1.4
FMI-BI (kg·m^{-2})	3.5±1.0	6.0±3.0
FFMI-BI (kg·m^{-2})	18.6±1.8	16.2±1.6

BMI: body mass index, FMI-SF: fat mass index by skinfold thickness, FFMI-SF: fat-free mass index by skinfold thickness, FMI-BI: fat mass index by bioelectrical impedance, FFMI-BI: fat-free mass index by bioelectrical impedance.

3. RESULTS AND DISCUSSIONS

Somatochart of the college athletes was shown in Figure 1. Female athlete's distribution area was more endomorphy in comparison with male athletes. Throwers were distributed over endo-meso direction compared with others in male and female athletes.

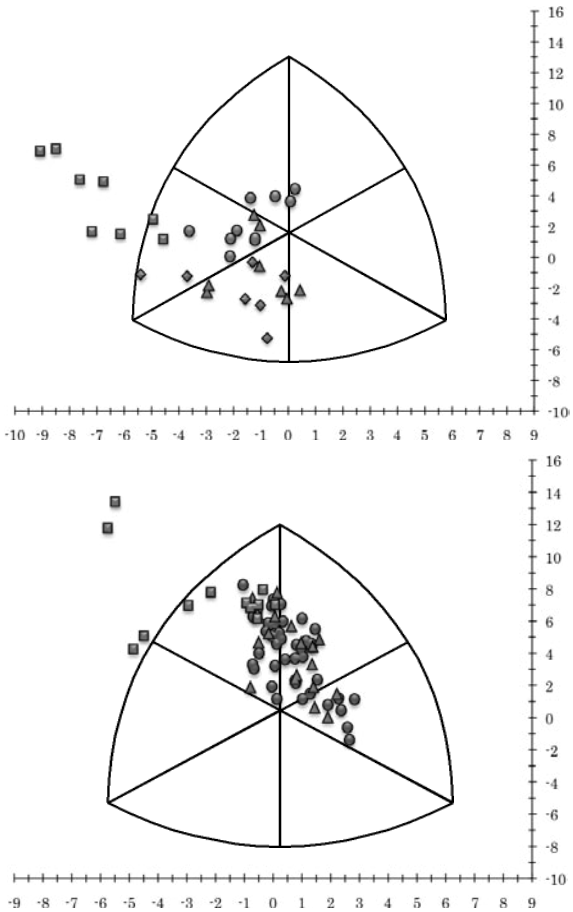


Figure 1: Somatochart in male (top) and female (bottom) athletes

Circle: Sprinter, Diamond: Distance runner, Triangle: Jumper, Square: Thrower

The relationships between body compositions and each somatotype component were shown in Figure 2. High correlations above 0.8 were obtained between each component of somatotype and FMI or FFMI in both male and female athletes as shown by straight line. Mesomorphy was significantly related to both FFMI-SF and -BI at male and female athletes. Slaughter and Lohman [3] demonstrated that fat-free mass and height used as independent variables to estimate somatotype closely related to mesomorphy. Because FFMI used as measure of fat-free mass in this study indicate fat-free mass standardized by height, present results for athletes could be consistent with their study for college-aged women. Similarly, endomorphy was also highly related to FMI-SF and -BI at male and female athletes except for FMI-BI at male athletes. Previous studies also found high relationship between endomorphy and body fat [3][8]. On the

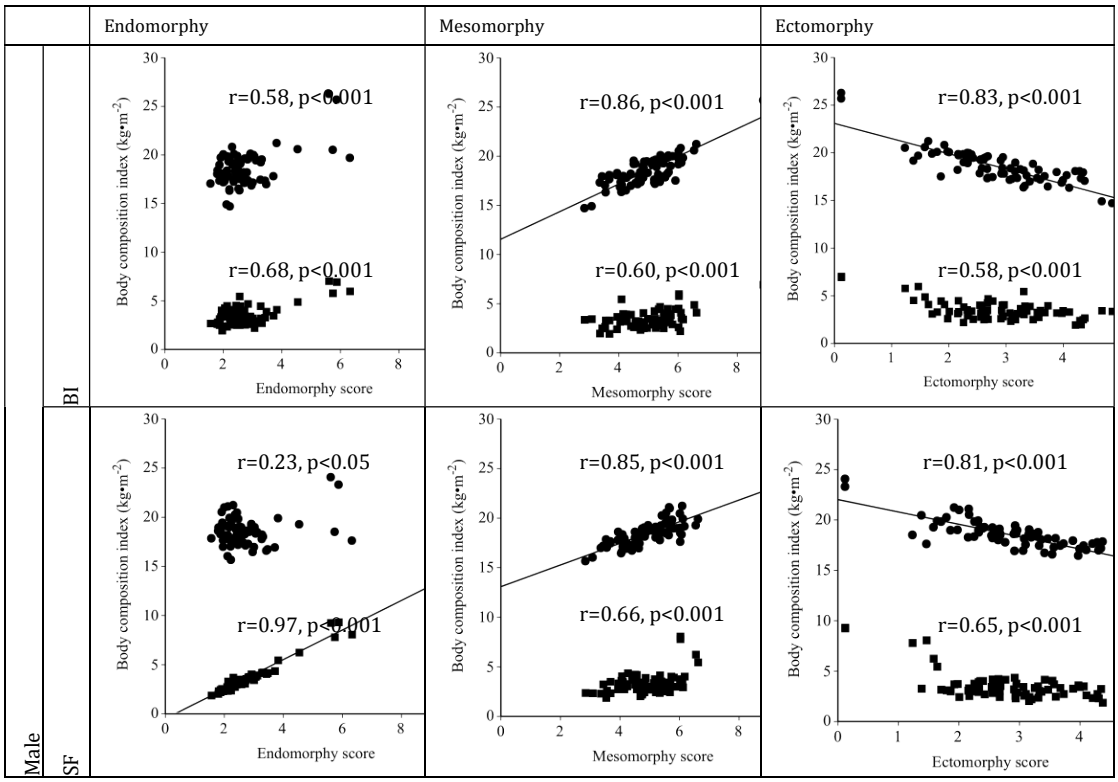
other hand, Ectomorphy indicated negative relation to FMI and FFMI at male and female athletes, but different tendency between male and female. These results indicated that there is strong positive relation between endomorphy and FMI, and mesomorphy and FFMI, and week negative relation between ectomorphy, and FMI and FFMI in male and female athletes.

Multiple regression analysis depending on the three somatotype components for predictive equations of body composition was listed in Table 2. The analysis indicated that a high accuracy (r=0.90-0.99) for prediction of body composition estimated by SF was found and all of three component scores were significantly predicted for FMI and FFMI. On the other hand, endomorphy and mesomorphy were good predictor of the criterion variable for FMI and FFMI by BI, respectively. Both body composition by SF and somatotype were calculated from anthropometric measurements. Therefore, these results that somatotype could predict body compositions were natural. However, body composition by BI was estimated from different principle. Close relationship between body compositions by BI and somatotype, estimated from different systems, would support present result that somatotype is useful for measuring body composition.

4. CONCLUSION

The relationship between somatotype and body composition was investigated to assess the utility of somatotype for measuring body composition. Consequently, it was confirmed that somatotype was significantly associated with body composition, especially, endomorphy and mesomorphy score could predict FMI and FFMI with high precision, respectively. These findings in the present study suggest that anthropometric somatotype rating would be useful as a measure of body composition in Japanese college track and field athletes.

(Figure 2 continues on page 67)



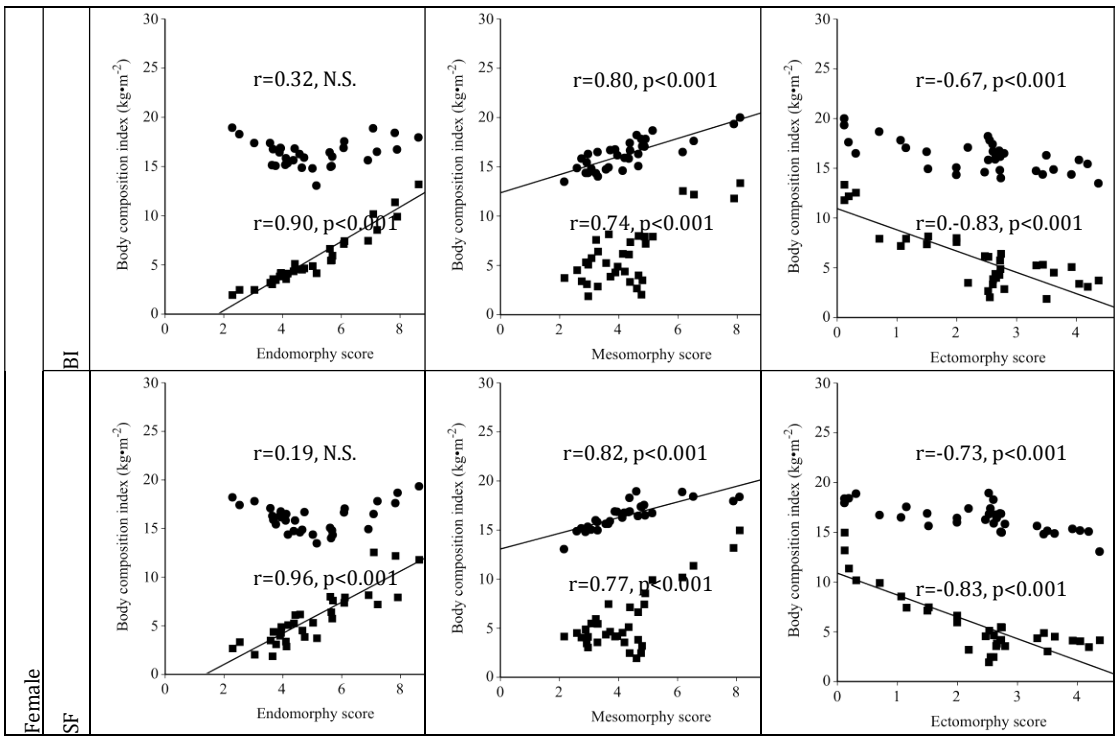


Figure 2: Relationship between body composition index and somatotype score of three components

Body composition index vs. endomorphy in left column, mesomorphy in middle column and ectomorphy in right column, respectively. Upper two and bottom two lines indicate in male and female athletes, respectively. Straight line in a graph indicate high correlation above r=0.8. SF: Skinfold thickness, BI: Bioelectrical impedance, Circle: Fat-Free mass index, Square: Fat mass index.

Table 2: Multiple regression analysis depending on three components of somatotype for prediction of body composition

Dependent variables		Regression equations	R	Adjusted R^2	SEE
FMI-SF	(Male)	1.38*·Endo-S + 0.39*·Meso-S + 0.22*·Ecto-S - 2.70	0.98	0.97	0.26
FMI-SF	(Female)	1.52*·Endo-S + 0.90*·Meso-S + 0.41*·Ecto-S - 6.75	0.99	0.99	0.38
FFMI-SF	(Male)	- 0.60*·Endo-S + 0.89*·Meso-S - 0.61*·Ecto-S + 17.42	0.90	0.82	0.61
FFMI-SF	(Female)	- 0.63*·Endo-S + 0.54*·Meso-S - 0.98*·Ecto-S + 19.67	0.96	0.93	0.38
FMI-BI	(Male)	0.54*·Endo-S + 0.31·Meso-S + 0.03·Ecto-S + 0.35	0.73	0.51	0.70
FMI-BI	(Female)	1.19*·Endo-S + 0.46·Meso-S - 0.35·Ecto-S - 1.18	0.94	0.86	1.12
FFMI-BI	(Male)	0.23·Endo-S + 0.96*·Meso-S - 0.43·Ecto-S + 14.37	0.87	0.75	0.91
FFMI-BI	(Female)	- 0.30·Endo-S + 0.98*·Meso-S - 0.21·Ecto-S + 14.10	0.83	0.66	0.92

Endo-S: Endomorphy score, Meso-S: Mesomorphy score, Ecto-S: Ectomorphy score, FMI-SF: Fat mass index by skinfold thickness, FFMI-SF: Fat-free mass index by skinfold thickness, FMI-BI: Fat mass index by bioelectrical impedance, FFMI-BI: Fat-free mass index by bioelectrical impedance, R: Correlation coefficient, SEE: Standard error of estimate, *: $p<0.05$.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Komiya, S., Masuda, T. and Teramoto, K. (2002) Model for human body composition analysis and basic concepts underlying the generation of predictive equations. J. Health Sci. 24: 1-9.

[2] Carter, J.E.L. and Heath, B.H. (1990) Somatotyping – Development and applications. Cambridge Univ. Press, Cambridge.

[3] Slaughter, M. H. and Lohman, T. G. (1976) Relationship of body composition to somatotype. Am. J. Phys. Anthropol. 44: 237-244.

[4] Komiya, S. and Masuda, T. (1990) Estimation of human body composition by bioelectrical impedance measurements-equation for estimating total body water in Japanese subjects. Jpn. J. Phys. Fitness Sports Med. 39: 53-59.

[5] Lohman, T.G. (1986) Applicability of body composition techniques and constants for children and youths. Exerc Sport Sci Rev,Macmillan' New York 14: 325-57

[6] VanItallie, T.B., Yang, M-U., Heymsfirld, S.B., Funk, R.C. and Boileau, R.A. (1990) Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. Am. J. Clin. Nutr. 52: 953-959.

[7] Nakao, T. and Komiya, S. (2003) Reference norms for a fat- free mass index and fat mass index in the Japanese child population. J. Physiol. Anthropol. Appl. Human Sci. 22: 293-298.

[8] Bale, P. (1980) The relationship of physique and body composition to strength in a group of physical education students. Br. J. Sports Med. 14: 193-198.

Can wearing equipment for experiencing the elderly obtain characteristics of EMG activity by the elderly?

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ABSTRACT

This study aimed to evaluate whether or not wearing equipment for experiencing the elderly can reflect physiological as well as behavioral characteristics observed by the elderly. A total of four male subjects (Avg. 22.3yrs) with no records of musculoskeletal injuries in the lower extremity was recruited from university and participated in the experiment. Electromyogram data were measured for six muscles on the right lower extremity, which were major muscles characterizing locomotion. EMG activities with two conditions (control and wearing elderly simulator (ES) conditions) during climbing stairs were measured. Co-contraction indices in the stride cycle were calculated as the ratios of pairs of agonist and antagonist muscles. As a result, the average walking speed under ES condition was 74.6steps/min, whereas that under non-ES condition was 93.2steps/min, indicating 20 percents of the speed reduction. The result of the walking speed supported that the wearing equipment for simulating the elderly can represent walking speed by the elderly to some extent. Co-contraction indices were significantly different between two conditions, however, the muscular activities for tibialis anterior and vastus lateralis were not significantly affected by the condition. Although numbers of subjects were restricted, the trends from the results suggested that the muscular activity and angular changes in lower extremity generated by the wearing equipment may be difficult to simulate those found in walking patterns by the elderly, due to the lack of understanding for the characteristics of the wearing equipment. Future study includes additional experiments with using hip joint and leg fixation devices to evaluate whether the simulated activity becomes closer to the real elderly data since these joints in wearing condition were observed more dynamic than those in the real elderly data.

1. INTRODUCTION

When safety of houses and public areas are evaluated empirically, the population of the subjects participating to such experiment has to be wide ranged, i.e., including younger generation to older population because house and public areas are used by a broader range of people. It is, however in most cases, difficult to obtain empirical data especially from older populations in terms of safety for conducting experiments. Databases for physical fitness and anthropometry including elderly people have been constructed by many research groups (see [1], for example) and they have been used as an effective index especially for product designs. However, these databases cannot be applied effectively in cases such that complex motions and couplings with circumstances play an important role for the design of the object. By applying specific well-known characteristics observed by the elderly, which is an increasing tendency of postural sway by age for example, it is possible to conduct screening procedure to the aged users. However, the information obtained by such database is not still sufficient for designing a general guideline to the elderly. In our previous study [2], it was discussed that the design of urban underground for ensuring a safe evacuation by stairs during flooding has not fully investigated due to the limitation of the physical activity for aged population to be a subject for unsecured evacuation testing. This paper introduces the results of the observation associated with muscular activity for young subjects wearing a set of braces designed for experiencing the elderly (elderly simulators: ES). As a result of our pilot study using stair climbing tasks, this paper reports the similarity of the data between the elderly and the ES wearer with regard to muscular loads and the characteristics of joint motions. This paper also examines whether or not the data obtained by ES wearer can complement the data obtained by the real elderly for the purpose of alternative information of the elderly, where the elderly data cannot be obtained due to difficulty in measurement under unsafe environment.

2. METHODS

2.1 Subjects

The participants in this study were four male subjects (mean age, 22.3±0.5 yr). Their average height and body mass were 172.3±5.5 cm and 64.0±10.2kg, respectively. The recruited subjects were healthy individuals without any known

musculoskeletal diagnoses. All the subjects were informed about the procedures and potential risks.

2.2 Electromyograms

EMGs were collected for each muscle by using active electrodes (NM-512, Nihon Koden). The locations for the electrode attachment were prepared by shaving and abrading the skin by using a skin preparation gel, and the skin was cleaned with alcohol in order to obtain low inter-electrode impedance. EMG signals were measured for the following six muscles at the right lower extremity: the rectus femoris (RF), vastus lateralis (VL), long head of the biceps femoris (BF), tibialis anterior (TA), gastrocnemius medialis (GM), and gluteus maximus (GMA). A reference electrode was attached to the lateral epicondyle of the humerus.

EMG signals were collected using an eight-channel mutitelemter system (WEB-5000, Nihon Koden) and were transferred to a PC with an A/D converter, which was operated by the bio-signal monitoring system (QP-110H, Nihon Koden). Raw EMG signals were recorded at a sampling rate of 2 kHz and filtered with 600-Hz low-and high-pass filters at a 0.03-s time constant.

Maximum voluntary contraction (MVC) was used to normalize the EMG value across subjects. MVC was measured in accordance with Sawai et al. [3]. The total EMG activity for each muscle was expressed in terms of %MVC. The subjects performed two sets of MVC trials for each tested muscle, and the higher activity value obtained in the two trials was used as the MVC EMG value. The duration of each MVC trial was 3 s. The subjects rested for 1 min between trials. The EMG signals were converted to root-mean-square (RMS) signals, aligned with a stride cycle, and normalized by MVC. The stride cycle was determined by the signal generated using foot switches located under the heel and toe of the right leg.

As an index for quantifying imbalanced situation such as the situation expecting a sudden extra force by some disturbance, the percentage of co-contraction was calculated. Calculation of co-contraction was followed by Larsen et al [4], where two muscular loads from muscles A and B, having the relationship as agonist and antagonist muscles, were graphically expressed as the overlapping area in a stride cycle and obtained as the following equation,

Co-contraction [%] =

$$\frac{\int \min\{\text{muscle activity on muscle } A, \text{muscle activity on muscle } B\}dt}{\int \max\{\text{muscle activity on muscle } A, \text{muscle activity on muscle } B\}dt}$$

2.3 Experimental Procedure

Stairs consisted of 10 steps, each of which had 16.3 cm of riser and 30cm of tread was used. Two conditions were tested; climbing with and without ES (LM-060, Koken). ES consisted of knee braces, a back protector, weights on both wrists (500 g), and weights on both ankles (1kg). Figure 1 shows subject wearing ES. The ES kept subjects' back and waist less mobilized and required extra force to move their arm and foot. The ES used in the study was available especially for the people in nursing and social welfare programs to obtain the technique for the better quality of care to the elderly by experiencing physical restriction that supposed to simulate elderly person. The subjects were instructed to start climbing with their right foot. The location we analyzed was a stride cycle observed from fifth step to seventh step. A total of five trials for each condition were performed.

Figure 1: a subject wearing ES

3. RESULTS

The average cadences in stair-climbing under ES condition and non-ES condition were 74.6±11.5 steps/min and 93.2±8.5 steps/min, respectively, indicating 20 percents of the speed reduction by the effect of ES. Figure 2 shows the average muscular activity for each measured muscle in the stride cycle. Significant differences on the muscular activity of BF, TA, VL, and GMA between ES and non-ES condition were found. Figure 3 shows the differences in ES and non-ES condition represented as co-contraction indices of the upper thigh and the lower leg. For both the upper thigh and the lower leg, there were significant differences between ES and non-ES conditions.

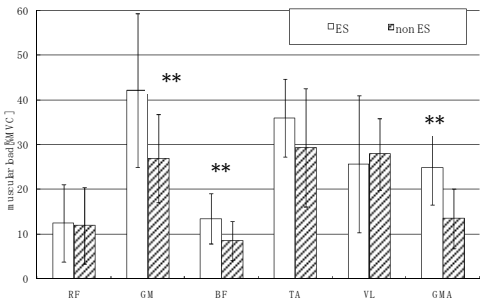

Figure 2: Muscular loads during ES and non ES condition

(rectus femoris (RF), long head of the biceps femoris (BF), tibialis anterior (TA), vastus lateralis (VL), gastrocnemius medialis (GM), gluteus maximus (GMA))**: p<0.01

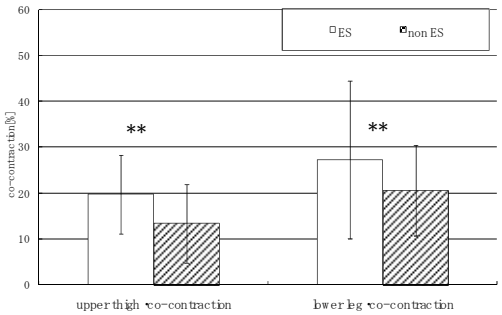

Figure 3: co-contraction indices for upper thigh and lower leg during ES and non ES condition.

Co-contraction of the upper thigh (rectus femoris and vastus lateralis versus long head of the biceps femoris and gluteus maximus), co-contraction of the lower leg (tibialis anterior versus gastrocnemius medialis) **: p<0.01

4. DISCUSSION

The average walking speed under ES condition was 74.6steps/min, whereas that under non-ES condition was 93.2steps/min, indicating 20 percents of the speed reduction. Walking speed in stair-climbing by the elderly has been reported differently; ranging from 50.4steps/min [4] and 145steps/min [6]. The result of the walking speed in our study supported that the wearing equipment for simulating the elderly can represent walking speed by the elderly to some extent.

Co-contraction indices were significantly different between two conditions; however, the muscular activities for TA and VL were not significantly affected by the condition. Larsen et al. [4] reported the results of muscular activity including differences in co-contraction between the younger and elderly population. They reported higher co-contraction indices in upper thigh and lower leg as well as higher muscular activities exerted by RF, VL, BF and some others in stair-climbing by the elderly. On the other hand, the results of ES wearing condition showed no significant differences in RF and VL. Larsen et al. [4] showed no significant differences on GM, whereas significant difference on GM was found in our study. These inconsistencies between current results and Larsen et al. [4] would lead to the conclusion that the ES was not accurately simulated muscular activities by the elderly. One of the reasons could be insufficient restriction by ES. ES only provided fixations on the knee, which yielded less activity on knee extensors, thus GM, as a plantar flexor of the toe, and GMA, as a hip flexor, were compensated for the immobilized knee joints.

Although numbers of subjects were restricted, the trends from the results suggested that the muscular activity and angular changes in lower extremity generated by the wearing equipment may be difficult to simulate those found in walking patterns by the elderly, due to the lack of understanding for the characteristics of the wearing equipment.

Future study includes additional experiments with using hip joint and leg fixation devices to evaluate whether the simulated activity becomes closer to the real elderly data since these joints in wearing condition were observed more dynamic than those in the real elderly data.

5. REFERENCES

[1] Steenbekkers, LPA. & van Beijsterveldt, CEM. (1998). Design-relevant characteristics of ageing users: Backgrounds and guidelines for product innovation, Delft University Press, Delft, Netherland.

[2] Kotani, K., Hirato, Y., Ishigaki, T., Shimada, H., Toda, K. & Horii, K. (2007). An EMG study of walking in flood water for evacuation from urban underground, Proceedings of the International Conference on Slips, Trips, and Falls 2007: From Research to Practice, Eds.: Chang, W-R. & Chang, C-C. M., IEA Press, MA., USA.

[3] Sawai, S., Sanematsu, H., Kanehisa, H., Tsunoda, N. & Fukunaga, T. (2004). Evaluation of muscular activity level in daily actions. Japanese Society of Physical Fitness and Sport Medicine, 53, 93-106. (In Japanese with English Abstract)

[4] Larsen, AH., Puggaard, L ., Hämäläinen, U. & Aagaard, P . (2008). Comparison of ground reaction forces and antagonist muscle coactivation during stair walking with ageing, Journal of Electromyography and Kinesiology, 518(4):568 - 580.

[5] DeVita P. & Hortobagyi T. (2000). Age causes a redistribution of joint torques and powers during gait, Journal of Applied Physiology, 88(5): 1804-1811.

[6] Adachi, K., & Okada, M. (2002). Part 2. Walking of old people. 2.3. Stair walking of old people, 185-217. (In Japanese)

Reproducibility and acclimatization of finger temperature responses to ice water

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ABSTRACT

The aim of this study is to evaluate the reproducibility of the cold-induced vasodilation (CIVD) response in a single finger immersed in ice water from the viewpoint of within-subject variability in the onset time, the minimum (Tmin) and the mean finger skin temperatures (Tmean). Furthermore, changes in peripheral cold acclimatization are examined under the conditions of repeated exposure to cold stress. Measuring sites were at the nail bed and the pad of the index finger of the right hand, and skin temperatures were recorded every 6 seconds with a data logger. Before ice water immersion, skin and oral temperatures at rest were measured for 10 minutes. Then, the index finger was immersed up to the middle phalanx in ice water at 0 degrees C for 30 minutes, followed by a 10 minute recovery period at the ambient air temperature. Five subjects came into the laboratory ten times within a month for treatment to investigate the effect of repeated immersion on reproducibility and acclimatization of CIVD. Reproducibility of the parameters (onset time, Tmin and Tmean) was expressed as the standard deviation, the coefficient of variation (CV), and the range of ten trials for each subject. The effect of acclimatization was tested by regression analysis between the parameters and the number of trials.

The onset time at the nail bed was slightly longer than that at the pad of the index finger. The mean values of Tmin were almost equal to the temperature of the surrounding ice water. The mean values of Tmean for all subjects were 3.6 degrees C on the nail bed and 7.1 degrees C on the pad. The temperature reactions measured on the pad are more sensitive than are those on the nail bed. The present study showed that within-subject CV on the nail bed and pad were 6.6 and 5.9 percent for onset time, 29.9 and 32.6 percent for Tmin, and 26.4 and 22.1 percent for Tmean, respectively. It appeared that the reproducibility was better for the onset time than for the Tmin and Tmean. In a few subjects, the onset time was positively correlated, and the Tmin and Tmean negatively correlated, with the number of trials. The results indicated that repeated cold exposure of a single finger may have a tendency to decrease vasodilation responses.

1. INTRODUCTION

It is well known that peripheral cold adaptability is often tested by means of the cold-induced vasodilation response (CIVD). Japanese investigators, Yoshimura and Iida (1950), proposed a point test on the CIVD and named it a resistance index. In this test, a single finger is immersed in ice water for 30 minutes, and skin temperature changes in the finger tip are measured from moment to moment. The result of the test is expressed as a point system calculated from onset time, minimum skin temperature and mean skin temperature; that is, the period from immersion to the time when minimum skin temperature appears, the lowest skin temperature just before CIVD starts, and the mean value of skin temperature from 5 to 30 minutes immersion, respectively. Although recent studies have employed finger immersion in water at relatively higher temperature to avoid painful sensations during the experiment, ice water immersion is still worthwhile because it is a simple method for instrumental setting and there are many previous studies with which to compare data.

However, few investigations have been done on the reproducibility of the CIVD response in the fingertip. Yoshimura and Iida (1950) measured finger skin temperature during ice water immersion every 2 or 4 days for about a month and found the maximum variation of resistance index to be ±1 point. Recently, O'Brien (2005) carried out finger immersion tests in the 4 degrees C water and showed that within-subject coefficient of variation across the five tests for the nail bed and pad were 9 and 21 % for minimum skin temperature, 18 and 19 % for onset time, and 10 and 15 % for mean skin temperature, respectively. Meanwhile, to my knowledge, there are no studies that have examined the reproducibility of the CIVD response in ice water.

On the other hand, this reproducibility may be partly affected by a cold acclimatization because of repeated cold exposures. Some studies (Adams and Smith, 1962; Savourey et al., 1996) described that acclimatized people have shown increased skin temperature in cold environments. Other investigators (Leftheriotis et al., 1990; Bridgman,

1991; Geurts et al., 2005) have shown a decreased skin temperature after cold acclimatization. The discrepancy of these findings is probably due to the different experimental conditions, such as frequency, duration, and magnitude of cold exposure.

The aim of this study is, therefore, to evaluate the reproducibility of the CIVD response in a single finger immersion in ice water, from the viewpoint of within-subject variability in the onset time, the minimum and mean finger skin temperatures. Furthermore, changes in peripheral cold acclimatization are investigated under the conditions of repeated exposure to cold stress.

2. METHODS

This study was conducted using five subjects as shown in Table 1. All subjects were healthy and volunteered to participate in this experiment and all signed an informed consent form.

Data collection was carried out during summer holidays in August and September. Air temperature in the laboratory was maintained at around 27 degrees C for all trials. Arriving at the laboratory, subjects assumed a sitting posture on a chair for enough time to rest. During that time, thermistors (ITPO10-12, NikkisoYSI, Japan) were attached with surgical tape. Measuring sites were at the nail bed and the pad of the middle finger of the right hand. A data logger (LT-8A, Gram, Japan) recorded skin temperatures every 6 seconds.

Before ice water immersion, skin and oral temperatures at rest were measured for 10 minutes. Oral temperature was measured with a mercury thermometer (No 531-2311, Sefute, Japan). Next, the middle finger was immersed up to the middle phalanx in ice water at 0 degrees C for 30 minutes, followed by a 10 minute recovery period at the ambient air temperature. During the first 10 minutes of ice water immersion, subjects were asked to rate their finger pain every minute with a continuous scale from 0% as "no pain at all" to 100% as "intolerable pain". The subjects came into the laboratory ten times within a month to participate in the investigation of repeated immersion effect on reproducibility and acclimatization of CIVD. All tests were carried out in the morning at the same time of day.

The changes in finger skin temperature profile during ice water immersion were quantified using the following terminology. The minimum temperature (Tmin) is the lowest skin temperature just before the start of CIVD. The onset time is the time from the beginning of immersion to Tmin. The mean skin temperature (Tmean) is the average between 5 and 30 minutes of immersion. In addition, resistance index, devised by Yoshimura and Iida (1950), is calculated after a scoring system based on the parameters of Tmin, onset time, and Tmean.

Reproducibility of each parameter was expressed as the standard deviation (SD), the coefficient variation (CV), and the range for ten trials. Effect of acclimatization was investigated by means of regression analysis between the parameters and the number of trials of immersion. The correlation coefficients were tested at the significance level of 0.05.

3. RESULTS

Figure 1 shows the representative time course of finger skin temperature in a subject during ice water immersion. The upper and lower graphs are data for the nail bed and the pad of the middle finger, respectively. Lines consist of ten trials in the experiments. Including other subjects, the temperature reactions measured on the pad are more sensitive than those on the nail bed.

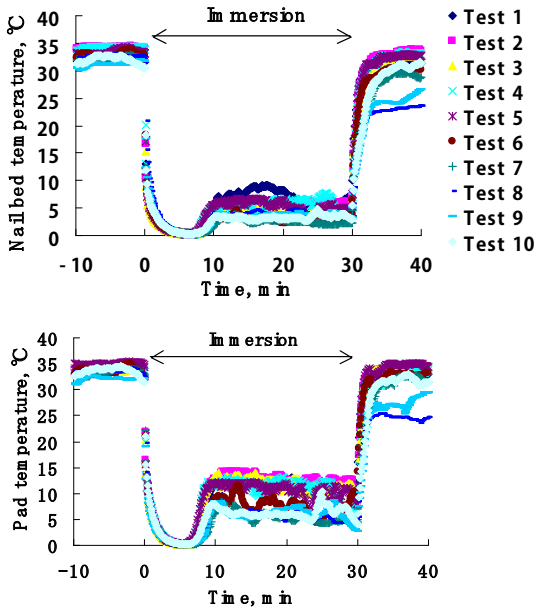

Figure 1. The representative time course of finger skin temperature in a subject during ice water immersion.

Table 1. Means and variations of parameters in CIVD observed during ten trials for each subject.

Subject	Sex	Age, yr	Onset time, sec				Tmin,				Tmean,				Resistance index			
			MEAN	SD	CV	RANGE	MEAN	SD	CV	RANGE	MEAN	SD	CV	RANGE	MEAN	SD	CV	RANGE
Nail bed																		
A	F	18	442.2	20.6	4.7	66	0.3	0.05	15.7	0.2	3.8	1.16	30.8	3.6	5.4	0.52	9.6	1
B	F	18	409.2	16.9	4.1	54	0.2	0.06	28.7	0.2	2.9	0.88	30.1	2.4	5.2	0.42	8.1	1
C	F	18	433.2	33.9	7.8	102	0.3	0.07	25.4	0.2	4.3	0.97	22.4	3.4	5.6	0.70	12.5	2
D	M	24	465.6	40.9	8.8	132	0.4	0.20	45.7	0.6	3.3	0.77	23.0	3.1	4.7	0.67	14.4	2
E	M	54	448.8	37.1	8.3	102	0.5	0.17	33.9	0.5	3.7	0.96	25.9	3.1	5.0	0.67	13.3	2
mean			439.8	29.9	6.7	91.2	0.3	0.1	29.9	0.3	3.6	0.9	26.4	3.1	5.2	0.6	11.6	1.6
sd			20.8	10.5	2.2	31.3	0.1	0.1	11.1	0.2	0.5	0.1	3.9	0.5	0.3	0.1	2.6	0.5
Pad																		
A			384.6	23.7	6.2	84	0.2	0.03	16.6	0.1	7.9	2.58	32.9	6.3	6.5	0.53	8.1	1
B			363.6	12.1	3.3	36	0.3	0.07	25.0	0.2	7.0	1.69	24.2	5.9	6.5	0.71	10.9	2
C	as above		398.4	21.2	5.3	66	0.2	0.08	35.9	0.2	6.7	1.21	18.2	4.0	6.5	0.53	8.1	1
D			385.2	41.0	10.6	132	0.4	0.25	59.1	0.7	5.0	1.08	21.4	3.2	5.8	0.42	7.3	1
E			382.8	19.3	5.1	72	0.5	0.12	26.2	0.4	8.9	1.24	13.9	4.2	6.9	0.32	4.6	1
mean			382.9	23.5	6.1	78.0	0.3	0.1	32.6	0.3	7.1	1.6	22.1	4.7	6.4	0.5	7.8	1.2
sd			12.5	10.7	2.7	35.0	0.1	0.1	16.3	0.2	1.4	0.6	7.1	1.3	0.4	0.1	2.3	0.4

Table 2. Changes in onset time, Tmin, Tmean and resistance index during ten trials of the test.

Subject	Onset time		Tmin		Tmean		Resistance index	
	r	significance	r	significance	r	significance	r	significance
Nail bed								
A	0.125	ns	0.311	ns	-0.774	p<0.01	-0.711	p<0.01
B	-0.527	ns	0.290	ns	0.020	ns	-0.087	ns
C	-0.616	ns	0.622	ns	0.322	ns	0.367	ns
D	0.574	ns	-0.785	p<0.01	-0.059	ns	-0.571	ns
E	0.030	ns	-0.651	p<0.05	0.079	ns	0.000	ns
Pad								
A	0.124	ns	-0.406	ns	-0.896	p<0.01	-0.870	p<0.01
B	-0.517	ns	0.353	ns	-0.411	ns	-0.130	ns
C	-0.251	ns	0.047	ns	0.202	ns	-0.104	ns
D	0.660	p<0.05	-0.831	p<0.01	-0.611	ns	-0.435	ns
E	0.663	p<0.05	-0.545	ns	0.053	ns	-0.522	ns

Table 3. Changes in pain rating during ten trials of the test. Correlation coefficients (r) between the pain rating and the number of trials are shown at each elapsed time.

Subject	1 min after immersion		5 min after immersion		10 min after immersion	
	r	significance	r	significance	r	significance
A	0.174	ns	0.132	ns	0.000	ns
B	0.174	ns	0.391	ns	0.000	ns
C	0.000	ns	0.210	ns	-0.480	ns
D	-0.870	p<0.01	0.290	ns	0.245	ns
E	-0.418	ns	0.000	ns	0.313	ns

Means and variations of parameters in CIVD observed during ten trials are shown in Table 1. Sex and age of five subjects are also indicated in this table. Onset time at the nail bed was slightly longer than that at the pad of the index finger. The mean values of Tmin were almost equal to the temperature of the surrounding cooling medium of ice water. Since the CV is calculated as SD divided by the mean, the small mean value of Tmin nearly equal to zero might lead to a relatively large CV. On the contrary, Tmean observed in subject B was at least above 2.9 degrees C. The large difference between Tmin and Tmean suggests that pronounced CIVD responses occurred in all subjects.

Table 2 presents the changes in onset time, Tmin, Tmean and resistance index during ten trials of the test for each subject. Regression analyses were employed to evaluate these parameter changes. Regarding onset time, correlation coefficients were statistically significant at the site of the finger pad for subject D and E, and onset time gradually increased with the number of trials of the test. Finger temperatures tended to decrease for a few subjects; that is, significant correlation coefficients were found for subject D and E for Tmin, and for subject A for Tmean. The calculated resistance index significantly lowered for subject A.

Changes in pain rating over ten trials are shown in Table 3. To compare the pain ratings with each other, three elapsed times were considered; that is, 1 min, 5 min, and 10 min after immersion. Correlation coefficients between the pain rating and the number of trials were calculated at each elapsed time. At the time of 1 min after immersion, the pain rating significantly decreased with the trials for Subject D, although other subjects showed no change at any elapsed time.

4. DISCUSSION

O'Brien (2005) measured skin temperature of the finger nail bed and pad during CIVD in cold water at 4 degrees C. Twenty-one subjects were employed and tested on five separate days and the within-subject CV of skin temperature on the nail bed and pad were 18 and 19 % for onset time, 9 and 21 % for Tmin, and 11 and 16 % for Tmean, respectively. This contrasts with the findings of the current study, which shows that within-subject CV on the nail bed and pad were 6.6 and 5.9 % for onset time, 29.9 and 32.6 % for Tmin, and 26.4 and 22.1 % for Tmean, respectively. Compared to the values measured by O'Brien (2005), those in the present study are smaller for onset time, but larger for Tmin and Tmean.

Different protocols used in this previous study and our study may partly affect the reproducibility of CIVD responses. Before testing, O'Brien (2005) adopted a finger immersion in warm water at 42 degrees C for 15 min to standardize initial finger temperature, and this extra procedure may have influenced the results, affording the high reproducibility of Tmin and Tmean observed in the previous study. The smaller within-subject CV for onset time in the present study may be due to the differences in the surrounding cooling medium used. Ice water employed in the present study would produce a pronounced change in skin temperature and establishes the onset time clearly. Consequently, the reproducibility of CIVD during ice water immersion used in the present study seems to be good for the onset time, while body thermal status of the subjects should be preconditioned to get reproducible Tmin and Tmean in the test.

In a few subjects, the repeated cold exposure of a single finger to ice water caused an increased onset time and decreased Tmin and Tmean. This means that local cold acclimatization of the finger may cause slow thermal responses. As mentioned above, there are discrepancies in the acclimatized changes in the thermal response among the results obtained by various investigators. Increase in skin temperature was described by Adams and Smith (1962), and Savourey et al. (1996). In contrast, Leftheriotis et al. (1990), Bridgman (1991), and Geurts et al. (2005) demonstrated a decrease in skin temperature. Although different experimental procedures may indeed be one source of these opposite changes, the repeated cold stress test in the present study also showed a tendency for decreases in finger skin temperature, which implies enhanced vasoconstriction. This also may affect the reproducibility of the CIVD.

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5. REFERENCES

[1]Yoshimura H, Iida T (1950) Studies on the reactivity of skin vessels to extreme cold. Part 1. A point test on the resistance against frost bite. Jap J Physiol 1:147-159

[2]O'Brien C (2005) Reproducibility of the cold-induced vasodilation response in the human finger. J Appl Physiol 98:1334-1340

[3]Adams T and Smith R E (1962) Effect of chronic local cold exposure on finger temperature responses. J Appl Physiol 17:317-322

[4]Savourey G, Barnavol B, Caravel J P, Feuerstein C, Bittel J H M (1996) Hypothermic general cold adaptation induced by local cold acclimation. Eur J Appl Physiol 73:237-244

[5]Leftheriotis G, Savourey G, Saumet J L, Bittel J (1990) Finger and forearm vasodilatatory changes after local cold acclimation. Eur J Appl Physiol 60:49-53

[6]Bridgman S A (1991) Peripheral cold acclimatization in antarctic scuba divers. Aviat Space Environ Med 62:733-738

[7]Geurts C L M, Sleivert G G, Cheung S S (2005) Local cold acclimation of the hand impairs thermal responses of the finger without improving hand neuromuscular function. Acta Physiol Scand 183:117-124

Nutritional Status, Physical Activity, and Dietary Intake of Pygmy Hunter-gatherers in Cameroon

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ABSTRACT

The nutritional status, physical activity levels, and dietary intakes of eight married couples (n = 16) living in forest camps in Cameroon were examined. Individual levels of physical activity were monitored throughout the day and observed activities were classified into 46 categories. The total daily energy expenditure (TEE) was estimated for each individual using published energy expenditure values for specific tasks. However, information was not available for a number of unique activities (e.g., digging wild yams and cracking wild seed). In these cases, energy expenditure was measured in the field using indirect calorimetry (the Douglas bag technique). Dietary macronutrient intakes were estimated by weighing all foods brought to the camps, obtained by hunting and gathering, using the African food composition table. The edible and waste portions of each food were determined in field experiments. The mean BMI was 20.5 for men and 20.1 for women, which suggests that the subjects' nutritional status was generally good. The average daily energy intake for 20 days was balanced with the average daily energy expenditure during the same period. However, the daily physical activity varied widely among individuals in forest camps. For example, a day spent gathering wild yams on the mountain was more strenuous than activity patterns observed on other days. The average physical activity level (PAL = TEE/basal metabolic rate) fell into the "moderate to heavy" category based on the criteria set out by the World Health Organization for both genders. By contrast, we found that the same population, living in village camps, showed only "light" daily physical activity in a previous study. Our combined results indicate that Pygmy hunter-gatherers adapt themselves to local environments through the development of two contrasting lifestyles: a low energy intake/expenditure lifestyle in semi-settled village camps, and a much more energy intensive lifestyle in nomadic forest camps.

1. INTRODUCTION

The so-called Pygmies are the original inhabitants of the central African rainforests. They used to pursue a nomadic way of life, depending totally on forest products, before more recently beginning to include agricultural food sources. The study population is the Baka, one of the Pygmy groups that live in tropical rainforests across the Central African Republic, Republic of Congo, and Cameroon. Their population is estimated to be between 25,000 and 40,000 [1]. Settlement of this population began in the 1950s and remains in progress today. Their main subsistence activities are changing from hunting and gathering to agriculture.

While Pygmies have generally been considered the original inhabitants of the rainforest, recent studies have disputed the viability of subsistence in tropical rainforests by hunting and gathering alone [2-4]. Tropical rainforests are known as the most productive lands in the world, with an amazing diversity of flora and fauna. However, some researchers have asserted that food resources for human subsistence are rather scarce, spatially dispersed, and seasonally variable, especially in regard to energy sources. This question has not yet been resolved [5-8].

In this study, we aimed to assess the nutritional status, daily time allocation, physical activity, and dietary intake of Pygmy hunter-gatherers living in a forest camp to examine whether they can subsist healthily on forest resources alone without agricultural food sources.

2. SUBJECTS AND METHODS

2.1 Participants

The participants were eight married couples who were members of the Baka Pygmy hunter-gatherer people. They lived in southeastern Cameroon near the border with the Republic of Congo. Details of the study area and participants are provided elsewhere [9,10]. The participants were fully informed about the procedures and the purpose of the study, and their informed consent was obtained.

2.2 Measurements

We accompanied the eight married couples and their seven children to the forest camp and observed their hunting-gathering life for 20 consecutive days.

2.2.1 Anthropometry

Anthropometric dimensions were measured following standard protocols [11]. Height was measured to the nearest 1 mm using a field anthropometer (GPM, Switzerland), and body weight was measured to the nearest 0.1 kg. Body weight was measured daily between 05:00 and 05:30 in the morning, before breakfast. Body mass index (BMI) was calculated as body weight (kg)/height $(m)^2$.

2.2.2 Time allocation

To calculate total daily energy expenditure, we divided each 24-hour period into three phases: the observation period (12 h), a non-observation period (3 h), and sleeping time (9 h). The observation period started at 06:00 and ended at 18:00; during this period, each participant was carefully observed. We noted whenever a participant changed his or her activity and recorded the time to the minute. To assess energy expenditure, we adopted values from a previous study [12], where appropriate. To establish energy values for activities not previously given in the literature, we conducted field measurements (see 2.2.3 Measuring energy expenditure). The non-observation periods covered 3 h in total and occurred in the morning (05:30 to 06:00) and in the evening (18:00 to 20:30). We adopted an energy cost of 1.4× basal metabolic rate (BMR) for "maintenance activities" during this period [13]. BMR was adopted as the energy cost during the sleeping period (9 h, 20:30–05:30) [14].

2.2.3 Measuring energy expenditure (EE)

EE in resting positions (lying, sitting, and standing) was measured in the field using indirect calorimetry with the Douglas bag technique [15]. EE information was not available for a number of activities, such as digging wild yams and cracking wild seeds. In these cases, we simulated each specific activity in the field and measured the EE.

2.2.4 Daily step counts

Each participant wore a pedometer with a built-in accelerometer (Lifecorder EX, Suzuken, Japan) for 20 consecutive days. Unfortunately, valid acceleration data could not be obtained, but step count data were sufficient for analyses.

2.2.5 Dietary survey

All foods obtained by hunting and gathering and brought to the camps were weighed. Dietary macronutrient intakes were estimated using the African food composition table [16]. The edible and waste portions of each food were determined in field experiments.

2.2.6 Comparison between forest camp and village camp

We previously conducted physical activity and dietary surveys on the same population living in village camps (Yamauchi et al., 2000). Some of the data are shown in Tables 3 (physical activity) and 5 (dietary intake), and in Figure 2 (energy balance) as references.

No statistical analysis could be performed in these data because the methodology and the duration of data collection (i.e., person-days) are different between the two studies (forest vs. village).

Table 1: Physical characteristics of the participants (mean)

	Present study		**Previous study***	
	Men (N = 8)	Women (N = 8)	Men (N = 75)	Women (N = 73)
Stature (cm)	153	146	154	147
Weight (kg)	47.6	43.9	49.6	44.4
BMI	20.1	20.5	20.8	20.6

3. RESULTS AND DISCUSSION

3.1 Nutritional Status

The anthropometry results are shown in Table 1. The mean stature, body weight, and BMI were almost identical to those for a larger sample reported in a previous study [17]. The mean BMI was within the normal range ($18.5 \leq BMI < 25.0$), suggesting that participants' nutritional status was generally good. Figure 1 shows the daily variations in body weight for the men, women, and their seven children. The body weights of adult men and women remained stable; interestingly, the children's body weights tended to increase during the study period.

3.2 Daily time allocation

Observed activities were classified into 46 categories, which were further sorted into 13 broad groupings (Table 2). Gender differences were observed in daily time use. Hunting activity was observed only in men, and cooking activity was seen mostly in women. Men spent a larger proportion of their time in the forest (out of camp) than did women (mean: 381 vs. 264 min/day).

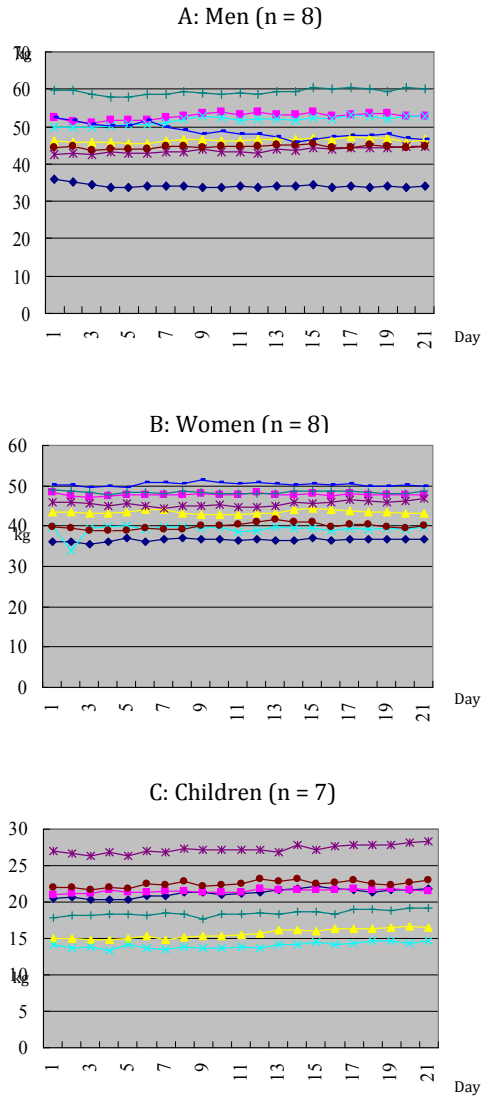

Figure 1: Daily variation in body weight

Table 3: Physical activity indices

	Forest[1]		Village[2]	
	Men N = 8*	Women N = 8*	Men N = 6*	Women N = 6*
PAL[3]	1.87	1.74	1.41	1.56
Category[4]	M-H	M-H	Very L	L
STEP[5]	10,878	8,034	NA	NA

[1]Present study, [2]Yamauchi et al., 2000 [17], [3]Physical activity level (TEE/BMR), [4]L: Light, M: Moderate, H: Heavy (FAO/WHO/UNU, 1985 [13]), [5]Step counts (step/day). *Person-day(s).

Table 2: Daily time allocation (min/day)

Activity	Men (N = 8)	Women (N = 8)	*P*
Forest			
1. Hunting	19	0	0.04
2. Gathering	132	137	NS
3. Travelling	158	105	NS
4. Rest	72	22	0.04
Camp			
5. Household	14	28	NS
6. Cooking	7	83	<0.0001
7. Manufacturing	30	64	NS
8. Eating	51	48	NS
9.Communication	29	11	NS
10. Personal	18	14	NS
11.Sleeping (daytime)	1	6	NS
12. Rest	181	201	NS
13. Strolling	9	1	0.02
Total	760	760	

3.3 Physical Activity

The average physical activity level (PAL: total EE [TEE]/BMR) was classified as moderate to heavy for both sexes, based on the criteria established by the World Health Organization (WHO) [13] (Table 3). By contrast, in a previous study, we found that the same population living in village camps showed only light daily physical activity [17]. In the present study, we found a significant positive correlation between PAL and daily step counts ($N = 16$, $r = 0.87$, $P < 0.0001$). These results suggest that walking is an important contributor to daily physical activity in forest life, as it is in village life [17].

Table 4: Dietary survey

Food	Weight (kg)	Energy (kcal)	%	Protein (kg)	%
Yam	626.7	626650	68.3	9.7	24.3
Game	107.6	118360	12.9	23.3	58.4
Fish	6.5	6500	0.7	1.1	2.8
Ant	8.6	8122	0.8	0.1	0.3
Honey	0.1	16	0.0	0	0.0
Nuts	25.5	126990	13.8	3.9	9.8
Others	8.6	8122	0.8	0.1	0.3
Total	783.5	917254	100.0	39.9	100.0

Table 5: Daily energy, protein intake

	Energy (kcal/day)	Protein (g/day)	Animal protein (%)
Forest camp[1]	2,211	93.5	66
Village camp[2]	1,666	47.9	52

[1]Present study, [2]Yamauchi et al., 2000 [17] (12 person-days).

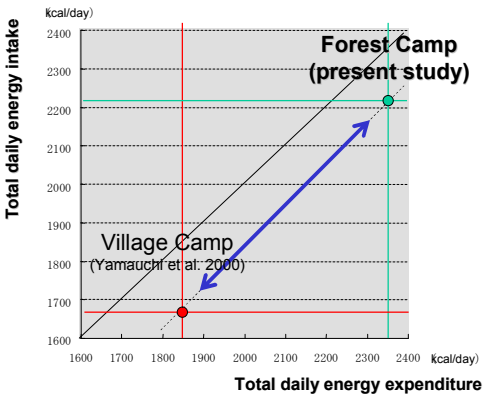

Figure 2: Energy balance: forest vs. Village

3.4 Dietary intake

Wild yams constituted the largest energy source, and game meat was the largest protein source (Table 4). Nuts also contributed significantly to both energy and protein intake. Participants living in the forest camp showed energy intake 1.3 times as great and protein intake twice as great as those observed among people living in the village camp (Table 5). The average daily energy intake over 20 days was well balanced with the average daily energy expenditure during the same period. Protein intake was estimated to be 2 g per 1 kg body weight and 17% of energy intake. These results suggest that protein intake was also sufficient in the forest camp.

3.5 Energetic Adaptation in the Forest and Village

Two contrasting models of energy balance were observed in forest and in village camps (Fig. 2). The village camp is characterized by low energy intake and expenditure, whereas the forest camp is characterized by high energy intake and expenditure.

In summary, eight families were able to live healthily in the forest camp, depending only on forest resources. Our combined results indicate that Pygmy hunter-gatherers adapt to local environments by developing two contrasting lifestyles: a low energy intake/expenditure lifestyle in semi-settled village camps and a much more energy-intensive lifestyle in nomadic forest camps.

4. REFERENCES

[1] Joiris, D.V. (1998). *La Chasse, La Chance, La Chant: Aspects du System Rituel des Baka du Cameroun*. Ph.D. thesis, Université Libre de Bruxelles.

[2] Hart, T.B.,& Heat, J.A. (1986). The ecological basis of hunter-gatherer subsistence in African rain forests: The Mubuti of eastern Zaire. Human Ecology, 14: 29-55.

[3] Headland, T.N. (1987). The wild yam question: How well could independent hunter-gatherers live in a tropical rain forest ecosystem? Human Ecology, 15: 463-491.

[4] Bailey, R.C., Head, G., Jenike, M., Owen, B., Rechtman, R., & Zechenter, E. (1989). Hunting and gathering in tropical forest: Is it possible? American Anthropologist, 91: 59-82.

[5] Bailey, R.C., & Headland, T.N. (1991). The tropical rainforest: Is it a productive environment for human foragers? Human Ecology, 19: 261-285.

[6] Headland, T.N. (1997). Revisionism in ecological anthropology. Current Anthropology, 38: 605-630.

[7] Sato, H. (2001). The potential of edible wild yams and yam-like plants as a staple food resource in the African tropical rain forest. African Study Monographs Suppl.26: 123-134.

[8] Yasuoka, H. (2006). Long-term foraging expedition (Molongo) among the Baka hunter-gatherers in the northwestern Congo Basin, with special reference to the "wild yam question". Human Ecology, 34: 275-296.

[9] Sato, H. (1998). Folk etiology among the Baka, a group of hunter-gatherers in the African rainforest. African Study Monographs, Suppl.25: 33-46.

[10] Hayashi, K. (2008). Hunting activities in forest camps among the Baka hunter-gatherers of southeastern Cameroon. African Study Monographs, 29: 73-92.

[11] Weiner, J.S., & Lourie, J.A. (1981). *Practical Human Biology*. Academic Press, London.

[12] Benefice, E., & Cames, C. (1999) Physical activity patterns of rural Senegalese adolescent girls during the dry and rainy seasons measured by movement registration and direct observation methods. European Journal of Clinical Nutrition, 53:636-43.

[13] FAO/WHO/UNU Expert Consultation. (1985). *Energy and Protein Requirements*. Technical Report Series 724. World Health Organization, Geneva.

[14] Yamauchi, T. (2007). Modernization, nutritional adaptability, and health in Papua New Guinean Highlanders and Solomon Islanders. In: R. Ohtsuka R, S. J. Ulijaszek (eds.), *Health Change in the Asia-Pacific Region*, Cambridge University Press, Cambridge. pp.101-126.

[15] Douglas, C.G. (1911). A method for determining the total respiratory exchange in man. Journal of Physiology, 42:17–18.

[16] Leung, W.W. (1968). *Food Composition Tables for Use in Afria*. Food and Agriculture Organization, United Nations, Rome.

[17] Yamauchi, T., Sato, H., Kawamura, K. (2000). Nutritional status, activity pattern, and dietary intake among the Baka hunter-gatherers in the village camps in Cameroon. African Study Monographs, 21: 67-82.

Design for Living

Lighting and human wellbeing

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ABSTRACT

Humans adapt to the natural light-dark cycle according to the rotation of the earth on its axis. Many physiological, endocrinal and behavioral functions have a circadian rhythm and they are modulated by light signals that are transmitted from the retina to the circadian pacemaker in the brain. Natural sunlight changes dynamically depending on the weather, geographic conditions and season. It is known that maladaptations to short durations of natural sunlight in winter include seasonal affective disorder and disturbance of circadian rhythm. Artificial bright light is useful for avoiding unfavorable effects of short duration of natural sunlight. Humans in modern society receive benefits of artificial light. However, recent studies have shown that artificial light at night could have negative impacts on human circadian rhythm, health and wellbeing. Physiological responses to light depend on time of day, spectrum of light and season. Furthermore, there are large individual or population differences in responses to light. These variations should be considered to design a lighting environment from the perspective of human wellbeing.

1. INTRODUCTION

To generate an image of the world such as color, shape and movement, information of light is received at the retina and it is then transmitted to the visual brain area via the lateral geniculate nucleus (LGN) (Fig. 1). Light-dark information received by the retina is also transmitted to the suprachiasmatic nucleus (SCN), the center of the biological clock. Light affects human circadian rhythm, melatonin secretion, autonomic nervous system, central nervous system and mood. This is an unconscious process that is called non-image forming effects or non-visual effects of light.

Humans have evolved under the natural light-dark cycle according to the rotation of the earth on its axis, and many human physiological, endocrinal and behavioral functions have a circadian rhythm. Human circadian rhythm is generated by an internal biological clock that exists in the suprachiasmatic nucleus (SCN) in the hypothalamus. As the period of endogenous human circadian rhythm without any time cure is a little longer than 24 hours[1], humans have to adjust it to 24 hours every day. Light has an important role in entraining human circadian rhythms to a geophysical 24-h day.

In modern society, humans have succeeded in exclusion of the dark night from the life space and work place by obtaining artificial light. Despite the benefits of artificial light, recent studies have shown that artificial light at night has negative impacts on human sleep, circadian rhythm and health [2]. The use of fluorescent lamps became popular after the 1940's, and only half a century has passed since humans started to spend nights under bright lights. Numerous studies have begun to uncover the effects of artificial light on human circadian rhythm and physiology.

Effects of light vary greatly depending on various factors such as time of day, spectrum of light and season. In addition, there is large inter-individual difference in the physiological responses to light. These variations should be considered when we design a lighting environment from the perspective of human wellbeing.

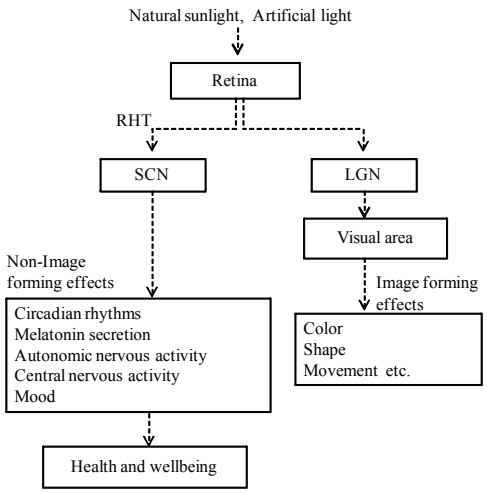

Figure 1: Human health and wellbeing through the non-image forming effects of light. (SNC: suprachiasmatic nucleus, RHT: retinohypothalamic tract, LGN: lateral geniculate nucleus)

2. TIME-OF-DAY EFFECTS OF LIGHT

2.1 Morning light

It is know that the period of human internal circadian rhythms is a little longer than 24 hours when we are isolated from any external time cue. Exposure to morning light after habitual rising time advances the acrophase of human circadian rhythm. In other words, exposure to morning light plays a role in resetting human circadian rhythm to 24 hours. This phase-advance effect of morning light begins from a few hours before waking. It has been reported that artificial dawn light stimuli have the potential to advance circadian rhythms in human [3]. Dawn light can also make feelings better on awakening. If your circadian rhythm tends to be delayed and if you have trouble awakening, benefits of morning light including dawn light should be considered.

2.2 Evening light

In contrast to morning light, evening light delays the acrophase of the circadian rhythms. Besides the benefits of artificial light at night, exposure to light at night has the potential to delay the circadian rhythm. In 1980, it was first demonstrated that melatonin was suppressed during exposure to bright light at 2500 lx in humans [4]. More recent studies have shown that even exposure to a light of several hundred luces can suppress nocturnal melatonin secretion [5], delay circadian rhythms [5] and increase alertness [6]. As this light intensity corresponds to the light intensity at home, artificial light at night may delay the circadian rhythms and disturb the sleep onset process. Furthermore, our study has shown that light from a computer display of 45 lx suppresses melatonin secretion at night. To prevent delay in circadian rhythms, exposure to artificial light before bed time should be considered.

Artificial light enables 24-hour working society. In the working place, bright light increases alertness of night workers and rapidly adapts the circadian rhythm for night work [7]. However, as for the dark side of artificial light at night, suppression of melatonin secretion by light has recently been suggested to increase cancer risk in night workers [2, 8].

2.3 Daytime light

Exposure to light during the daytime seems to influence the amplitude of circadian rhythm, although it has little impact on the acrophase of circadian rhythms in human. It has been reported that exposure to artificial bright light during the daytime increases melatonin secretion at night [9, 10]. The amplitude of circadian rhythms on body temperature and melatonin secretion tend to decrease in elderly people. Diminished amplitude of circadian rhythm is a possible cause of insufficient sleep for elderly. Daytime bright light from a fluorescent lamp or natural sunlight has a benefit for elderly people whose amplitude of circadian rhythm is diminished. In office workers, it has been found that bright light can prevent sleepiness after lunch that is called a post lunch dip.

3. SPECTRUM-DEPENDENT EFFECTS OF LIGHT

There have been noteworthy findings concerning human spectral sensitivity to the effects of light such as suppression of melatonin secretion, phase shift of endogenous circadian rhythm and enhancement of alertness. In 2001, an action spectrum for melatonin suppression by light in humans was reported by two groups [11, 12]. According to those studies, short-wavelength blue light (approx. 480 nm) has a greater impact on melatonin suppression, while the classical visual system is most sensitive to green light (555 nm). It was later shown that exposure to blue light also causes a phase shift of circadian rhythm and enhancement of alertness [13, 14].

This spectral sensitivity to non-visual effects of light has been found using not only a monochromatic light but also using a polychromatic light such as a fluorescent lamp. It was found that exposure to high color temperature light (5000K - 7000K) at night suppresses melatonin secretion [15] and reduces slow wave sleep [16] compared with exposure to low color temperature light (approx. 3000 K). Exposure to not only a bright light but also a high color temperature light should be avoided at night. A very low color temperature fluorescent lamp (2300 K) has recently been developed to prevent melatonin suppression at night [17].

On the other hand, high color temperature light has the merit of maintaining alertness. It has been reported that high color temperature light increases brain activity [18] [19] and autonomic nervous activity [20]. A very high color temperature lamp (17000 K) has recently been developed. It has been reported that this blue-enriched white fluorescent lamp improved self-reported alertness, performance and sleep quality in daytime workers [21].

4. SEASONAL, ETHNIC AND INDIVIDUAL VARIATIONS

Natural sunlight changes dynamically depending on the weather, geographic conditions and season. It is known that maladaptations to short duration of natural sunlight include seasonal affective disorder (SAD) and disturbance of circadian rhythm in winter [22]. SAD is caused by short duration of natural sunlight in winter. It has been reported that there are ethnic or eye color differences in prevalence of SAD [23, 24]. If short duration of sunshine acts as a stressor, there may be physiological adaptation to it. We therefore examined whether there are seasonal and ethnic differences in suppression of melatonin by exposure to light as a maker of circadian photosensitivity

To measure circadian photosensitivity, we focused on melatonin, which is secreted from the pineal gland during the night and shows a circadian rhythm. Melatonin secretion is easily suppressed by light exposure and it is very sensitive to light. Melatonin secretion is acutely suppressed by exposure to light at night. There is a dose-relationship between melatonin suppression and light intensity [25]. There are large individual differences in melatonin suppression by light [26]. Therefore, suppression of melatonin secretion is thought to be a good marker for evaluating individual photosensitivity of the circadian system.

4.1 Seasonal differences

First, to examine the adaptation to short duration of natural sunlight in winter, we compared the magnitudes of suppression of melatonin secretion by light at night in winter and summer. The study was carried out in Akita City (39º North), in the northern part of Japan, where the duration of sunshine in winter is the shortest in Japan. The subjects were exposed to white light (1000 lux) at night for two hours using white fluorescent lamps. We found that the inter-individual difference in melatonin suppression was smaller in winter than in summer and that the average percentage of suppression of melatonin two hours after the start of exposure to light was significantly larger in winter (66.6% ± 18.4%) than in summer (37.2% ± 33.2%). These results suggest that less exposure to daily ambient light in winter increases sensitivity of melatonin to light suppression. Increase in light sensitivity in winter is thought to be a kind of human physiological adaptation, although its mechanism has not been elucidated. It has been reported that suppression of melatonin in SAD patients is higher than that in healthy controls [27]. Does increase in sensitivity to light in winter help to prevent SAD? To answer this question, further study is needed to clarify the causal relationships between individual difference in sensitivity to light and the risk of SAD.

In this study, we measured the level of daily ambient light of each subject for 24 hours using a light sensor (Actiwatch-L, Mini-Mitter Co, Inc., USA). The level of daily ambient light to which the subjects were exposed from rising time to bedtime in summer was approximately two-times greater than that in winter. Subjects who were exposed to a large amount of ambient light in summer showed a low percentage of melatonin suppression. This result indicated that light history affects sensitivity of melatonin to light suppression. Some studies have also shown that much exposure to sunlight during the daytime reduces suppression of melatonin by light at night [28-30]. These studies suggest that exposure to sunlight during the daytime is another way to avoid the unfavorable effects of light at night.

4.2 Ethnic differences

We examined ethnic or eye color difference in photosensitivity [31]. The subjects were ten Caucasian males with blue/green irises or light-brown irises (light-eyed Caucasians) and eleven Asian males with dark-brown irises (dark-eyed Asians). They were exposed to white light (1000 lux) at night for two hours using white fluorescent lamps. There were large inter-individual variations in the percentages of melatonin suppression in dark-eyed Asians in comparison to those in light-eyed Caucasians. The percentage of suppression of melatonin secretion two hours after the start of bright light exposure was significantly larger in light-eyed Caucasians (88.9 ± 4.2%) than in dark-eyed Asians (73.4 ± 20.0%). The possible cause of the eye color-dependent difference seems to be related to intraocular light scattering in light-eyed Caucasians. The light transmittance through the eye wall and dispersion of light in the fundus oculi are thought to be larger in light-eyed Caucasians with less pigmentation than in dark-eyed people [32, 33]. Therefore, in the present study, photoreceptors might have received more light by dispersion of light in light-eyed Caucasians. However, the percentages of melatonin suppression in some dark-eyed Asians were as large as those in light-eyed Caucasians, indicating that some ethnic factors other than eye color may have contributed to the difference between melatonin suppression in dark-eyed Asians and that in light-eyed Caucasians. Although it is not clear whether Caucasians acquired blue eyes as a result of adaptation to a short duration of sunshine, blue eyes might have been advantageous for prevention of seasonal affective disorders in ancient times without artificial lighting.

4.3 Inter-Individual difference

Even under the conditions of the same season, same population and no difference in light history, it has been shown that there is large inter-individual difference in melatonin suppression by light [34]. Since exposure to light at night causes phase delay of circadian rhythm, individual difference in photosensitivity may be related to circadian rhythm and sleep habits. It has been reported that the magnitude of melatonin suppression by light in patients with delayed sleep phase syndrome (DSPS) was larger than that in healthy controls [35]. It is thought that hypersensitivity to light is related to delayed bedtime because exposure to light at night has the potential to delay the circadian rhythm. We examined the relationship between melatonin suppression by light and habitual bedtime in healthy subjects.

Contrary to our expectation, there was no significant relationship between individual difference in rate of melatonin suppression and habitual bedtime. However, there were two subjects in whom melatonin suppression did not occur. This suggests that there are some people who have very low sensitivity to suppression of melatonin by light. Furthermore, the two subjects in whom melatonin suppression did not occur had earlier habitual bedtimes than those of the subjects with suppression of melatonin.

Further study is needed to examine the causal relationships between individual difference in response to artificial light and circadian rhythm and sleep habit.

5. CONCLUSIONS

There are both light and dark sides of artificial light. Despite the benefits of artificial light, exposure to light at night has a possible negative impact on human circadian rhythms and wellbeing. What should be done to avoid unfavorable effects of light? Physiological responses to light depend on time of day, spectrum of light and season. Furthermore, there are large individual or population differences in responses to light. Reliable scientific knowledge will enable cultural adaptation, including behavioral and instrumental adaptation, to avoid unfavorable effects of artificial light. This scientific evidence should be considered in designing a lighting environment from the perspective of human wellbeing.

6. REFERENCES

[1] Czeisler, C. A., Duffy, J. F., Shanahan, T. L., Brown, E. N., Mitchell, J. F., Rimmer, D. W., et al. (1999). Stability, precision, and near-24-hour period of the human circadian pacemaker. Science, 284(5423), 2177-2181.

[2] Stevens, R. G., Blask, D. E., Brainard, G. C., Hansen, J., Lockley, S. W., Provencio, I., et al. (2007). Meeting report: the role of environmental lighting and circadian disruption in cancer and other diseases. Environmental health perspectives, 115(9), 1357-1362.

[3] Danilenko, K. V., Wirz-Justice, A., Krauchi, K., Cajochen, C., Weber, J. M., Fairhurst, S., et al. (2000). Phase advance after one or three simulated dawns in humans. Chronobiol Int, 17(5), 659-668.

[4] Lewy, A. J., Wehr, T. A., Goodwin, F. K., Newsome, D. A., & Markey, S. P. (1980). Light suppresses melatonin secretion in humans. Science, 210(4475), 1267-1269.

[5] Zeitzer, J. M., Dijk, D. J., Kronauer, R., Brown, E., & Czeisler, C. (2000). Sensitivity of the human circadian pacemaker to nocturnal light: melatonin phase resetting and suppression. J Physiol, 526 Pt 3, 695-702.

[6] Cajochen, C., Zeitzer, J. M., Czeisler, C. A., & Dijk, D. J. (2000). Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness. Behav Brain Res, 115(1), 75-83.

[7] Campbell, S. S., & Dawson, D. (1990). Enhancement of nighttime alertness and performance with bright ambient light. Physiol Behav, 48(2), 317-320.

[8] Schernhammer, E. S., Kroenke, C. H., Laden, F., & Hankinson, S. E. (2006). Night work and risk of breast cancer. Epidemiology (Cambridge, Mass, 17(1), 108-111.

[9] Mishima, K., Okawa, M., Shimizu, T., & Hishikawa, Y. (2001). Diminished melatonin secretion in the elderly caused by insufficient environmental illumination. J Clin Endocrinol Metab, 86(1), 129-134.

[10] Takasu, N. N., Hashimoto, S., Yamanaka, Y., Tanahashi, Y., Yamazaki, A., Honma, S., et al. (2006). Repeated exposures to daytime bright light increase nocturnal melatonin rise and maintain circadian phase in young subjects under fixed sleep schedule. Am J Physiol Regul Integr Comp Physiol, 291(6), R1799-1807.

[11] Brainard, G. C., Hanifin, J. P., Rollag, M. D., Greeson, J., Byrne, B., Glickman, G., et al. (2001). Human melatonin regulation is not mediated by the three cone photopic visual system. J Clin Endocrinol Metab, 86(1), 433-436.

[12] Thapan, K., Arendt, J., & Skene, D. J. (2001). An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. J Physiol, 535(Pt 1), 261-267.

[13] Cajochen, C., Munch, M., Kobialka, S., Krauchi, K., Steiner, R., Oelhafen, P., et al. (2005). High sensitivity

of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. J Clin Endocrinol Metab, 90(3), 1311-1316.

[14] Lockley, S. W., Brainard, G. C., & Czeisler, C. A. (2003). High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. J Clin Endocrinol Metab, 88(9), 4502-4505.

[15] Morita, T., & Tokura, H. (1996). Effects of lights of different color temperature on the nocturnal changes in core temperature and melatonin in humans. Appl Human Sci, 15(5), 243-246.

[16] Kozaki, T., Kitamura, S., Higashihara, Y., Ishibashi, K., Noguchi, H., & Yasukouchi, A. (2005). Effect of color temperature of light sources on slow-wave sleep. J Physiol Anthropol Appl Human Sci, 24(2), 183-186.

[17] Kozaki, T., Koga, S., Toda, N., Noguchi, H., & Yasukouchi, A. (2008). Effects of short wavelength control in polychromatic light sources on nocturnal melatonin secretion. Neurosci Lett.

[18] Noguchi, H., & Sakaguchi, T. (1999). Effect of illuminance and color temperature on lowering of physiological activity. Appl Human Sci, 18(4), 117-123.

[19] Deguchi, T., & Sato, M. (1992). The effect of color temperature of lighting sources on mental activity level. The Annals of physiological anthropology = Seiri Jinruigaku Kenkyukai kaishi, 11(1), 37-43.

[20] Kobayashi, H., & Sato, M. (1992). Physiological responses to illuminance and color temperature of lighting. The Annals of physiological anthropology = Seiri Jinruigaku Kenkyukai kaishi, 11(1), 45-49.

[21] Viola, A. U., James, L. M., Schlangen, L. J., & Dijk, D. J. (2008). Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health, 34(4), 297-306.

[22] Rosenthal, N. E. (1989). Seasons of the mind: Bantam Dell Pub Group (Trd)

[23] Goel, N., Terman, M., & Terman, J. S. (2002). Depressive symptomatology differentiates subgroups of patients with seasonal affective disorder. Depress Anxiety, 15(1), 34-41.

[24] Suhail, K., & Cochrane, R. (1997). Seasonal changes in affective state in samples of Asian and white women. Social psychiatry and psychiatric epidemiology, 32(3), 149-157.

[25] McIntyre, I. M., Norman, T. R., Burrows, G. D., & Armstrong, S. M. (1989). Human melatonin suppression by light is intensity dependent. J Pineal Res, 6(2), 149-156.

[26] Lewy, A. J., Nurnberger, J. I., Jr., Wehr, T. A., Pack, D., Becker, L. E., Powell, R. L., et al. (1985). Supersensitivity to light: possible trait marker for manic-depressive illness. The American journal of psychiatry, 142(6), 725-727.

[27] Thompson, C., Stinson, D., & Smith, A. (1990). Seasonal affective disorder and season-dependent abnormalities of melatonin suppression by light. Lancet, 336(8717), 703-706.

[28] Hebert, M., Martin, S. K., Lee, C., & Eastman, C. I. (2002). The effects of prior light history on the suppression of melatonin by light in humans. J Pineal Res, 33(4), 198-203.

[29] Rufiange, M., Beaulieu, C., Lachapelle, P., & Dumont, M. (2007). Circadian light sensitivity and rate of retinal dark adaptation in indoor and outdoor workers. J Biol Rhythms, 22(5), 454-457.

[30] Smith, K. A., Schoen, M. W., & Czeisler, C. A. (2004). Adaptation of human pineal melatonin suppression by recent photic history. J Clin Endocrinol Metab, 89(7), 3610-3614.

[31] Higuchi, S., Motohashi, Y., Ishibashi, K., & Maeda, T. (2007). Influence of eye colors of Caucasians and Asians on suppression of melatonin secretion by light. Am J Physiol Regul Integr Comp Physiol, 292(6), R2352-2356.

[32] IJspeert, J., de Waard, P. W., van den Berg, T. J., & de Jong, P. T. (1990). The intraocular straylight function in 129 healthy volunteers; dependence on angle, age and pigmentation. Vision Res, 30(5), 699-707.

[33] van den Berg, T. J., JK, I. J., & de Waard, P. W. (1991). Dependence of intraocular straylight on pigmentation and light transmission through the ocular wall. Vision Res, 31(7-8), 1361-1367.

[34] Higuchi, S., Motohashi, Y., Maeda, T., & Ishibashi, K. (2005). Relationship between individual difference in melatonin suppression by light and habitual bedtime. J Physiol Anthropol Appl Human Sci, 24(4), 419-423.

[35] Aoki, H., Ozeki, Y., & Yamada, N. (2001). Hypersensitivity of melatonin suppression in response to light in patients with delayed sleep phase syndrome. Chronobiol Int, 18(2), 263-271.

Cultural diversity and the consequences for human-product interaction

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ABSTRACT

This chapter discusses the role of cultural diversity in the area of designing the material world. On the 'user' side in the human-product interaction the focus is on the mental rather than physical aspects. Two perspectives are discussed; the designer perspective and the human need perspective. The first one focuses on the current interaction between human beings and the surrounding products as an expression of the reproduction of culture. The designer view shows dominance of the western culture in ' good' design. In the human need perspective the importance of designing products for society within a perspective of social and cultural responsibility and commitment will be stressed, so as to enable the promotion of emancipation, sustainable development, and improvement of quality of life as well as the cultural identities of individuals and social groups.

1. INTRODUCTION

One of the aims of physiological anthropology is to conduct research into humans in modern society from both a physiological and a cultural standpoint, in an effort to create a truly healthy and comfortable living environment. Until now the research community in the field has hardly taken the perspective of the material 'things' that support people in acquiring this comfortable life. Artefacts play an important role in the appropriation and (re)production of culture. They represent existing cultural categories. And people flexibly internalize these categories in interaction with objects. People and artefacts continuously create each other, especially during daily routine actions.

This specific view on the role of artefacts in people's everyday life has given rise to new research, but only recently the design disciplines take part in this research. They are not only interested in knowledge about material culture in understanding the past, but the more in how products can influence culture. Just as we create material culture, so too are we shaped by the material culture that surrounds us. As a specific area within cultural studies the interaction between people and products as a cultural phenomenon has hardly been described yet. In the discussion about culture in the context of design the issue of globalization is dominating. Some will argue that globalizing trends create a converging trend of standardization in form and function. While others argue that there are evidences of an increasing cultural sensitivity.

In order to meet the aims of creating a healthy and comfortable living environment a human need perspective can help. The importance of designing products for society within a perspective of social and cultural responsibility and commitment will be stressed, so as to enable the promotion of emancipation, sustainable development, and improvement of quality of life as well as the cultural identities of individuals and social groups.

In this chapter we, therefore, will focus on the human mind rather than on the biological basis of cultures – and specifically on the dynamic interaction between human mind and the designed material world. Many aspects of culture can be seen as mental adaptations and mental constructs that have endured over successive generations supposedly due to their evolutionary success. As culture influences every aspect of an individual's environment and behaviour, culture also needs to be considered in every aspect of a design-the physical environment. This approach contrasts with the paradigm in international design of simply exporting standard Western solutions and designs.

In most theories (Hofstede, 1991; Trompenaars & Hampden-Turner, 2002; Laroche, 2003) culture has been defined as a system of shared beliefs, values, customs, behaviours, and artefacts that members of a society use to cope with their world and with one another; and that are transmitted from generation to generation through learning. So, culture is not genetic or defined by birth. Culture manifests itself both in a visible (art, language, etc.) and a non-visible way (habits, preferences, experiences).

One well-known way of analyzing human culture was that of the Dutch anthropologist Hofstede, who developed his theories of cross-cultural communication through interviews and

questionnaire survey among people in many countries of the world.

On the basis of this research he distinguished five dimensions that describe different value perspectives between national cultures:

Power Distance. The degree of inequality among people that within a society is considered as normal.
Individualism/Collectivism. Te extent to which people feel they are supposed to take care, or to be taken care of by themselves, their family or organisations they belong to.
Masculinity/femininity. The extent to which a culture is conducive to dominance, assertiveness and acquisition of things; versus a society which is more conducive to people, feelings and the quality of life.
Uncertainty Avoidance. The extent to which people feel threatened by ambiguous situations, and have created beliefs and institutions that try to avoid these.
Long Term/Short Term Orientation. The extent to which a society exhibits a pragmatic future-oriented perspective rather than a normative historic or near term point of view.

Existing cultural models such as Hofstede's, however, do not provide extensive information about how it can be applied in a meaningful way to the field of designing, neither to designers' thinking nor to consumers' thinking. We need another way of thinking about how to study culture in such a way that it offers data that helps designers to design products that people need and love to use.

2. APPROACH

As a contribution to the discussion let us approach the study of cultural influences in two ways. One is to examine what designers do to cater for culturally diverse clienteles. The other is to examine the attitude or behaviour of people, the users of products. Within that approach their needs, wishes and expectation should be measured. Both have certain degrees of validity and can shed light on the subject under consideration. The first one is the common 'designerly' way of thinking; in order to get immediate design and marketing requirements the current interaction between human beings and the surrounding products - as an expression of the reproduction of culture - is studied. In Figure 1 the aspects design process (methodology, procedures), design education (transfer of design knowledge among other cultures), strategic decisions (in design and business), and the personal vision of the designer are designer-related. In the human need perspective the importance of designing products for the individual within social and cultural responsibility and commitment will be stressed. Preference for design in different cultures (aesthetics), semantics (interpretation of design and function) and human-product interaction (the actual use of products in different cultures) are user-related (Fig. 1).

Both perspectives will now be elaborated upon.

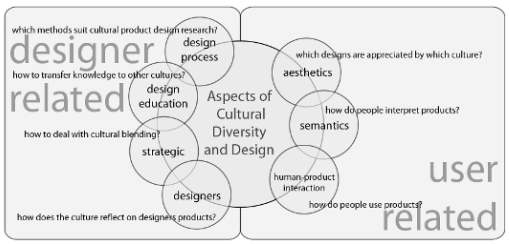

Figure 1: Mapping areas of cultural diversity and design (DeLeur et al., 2005)

3. THE DESIGNER PERSPECTIVE

All over the world, devices such as the cell phone and laptop computer are familiar icons of modern culture. In many areas international products and facilities follow the paradigm of using standard Western designs. As Dorst (2008) says: "The growing number of designers in the newly industrialising countries tend to get caught between the urge to remain faithful to the traditional culture of their countries and the idea that if they want to be considered to do 'good design', they would to be referencing Modernism." (Dorst, 2008, p. 2). This dominance of Modernism in the stylistic ideals of design in the Western cultures has had a huge impact, especially expressed in a loss of ornamental languages.

To illustrate the western dominance in design some specific product cases are presented here.

The iPod family (see figure 2) proves that the physical appearance of a product doesn't have to be different to be a success. But also the iPod is a highly diverse product, affected by the factor culture: the music on the iPod defines its cultural identity.

Figure 2: iPod Family

Western design magazines are the dominant media throughout the world (Fig. 3).

Figure 3: Western influence through magazines

Domestic appliances show similarity all over the world, be it kitchen utensils or personal care devices.

Figure 4: Cultural similarities to toast bread and appliances to get massage

By understanding that 'design' as we know it, is predominantly a child of western culture, what can we say about the local values brought to design? Even if the role a product plays in an international context becomes more and more important, there still are products that will express local values or are suitable for one specific context only. Despite the apparent universality of technology, it's a mistake to ignore differences—not only in culture, but also in age and gender—when working on user interface and design.

The older the product category the more cultural manifestations it has (de Mooij, 2004). Although the alignment of product designing with corporate guidelines and international trends is noticeable, the symbolic, practical and technical requirements vary among cultures, demanding product differentiation (Ono, 2005). No wonder that companies realize the importance of flexible and adaptive design according to local markets. A company's failure to acknowledge cultural differences often limits its product's marketability. Therefore, a number of global companies already started to develop methods and projects to study cross-cultural aspects. Intel developed his own 'Culture Capsule', a physical cultural environment that can simulate every cultural interior and atmosphere you like (Foucault and Russell, 2004). Microsoft, Hewlett Packard, Philips and Siemens, among others, are conducting cross-cultural studies to understand not only matters regarding culture and human interaction design but also how to gain profit from emerging markets.

From this designer perspective human beings are perceived as users irrespective their needs for the manufacturers' artefacts. Cultural-specific variables are related to users' expectancies about usability. Depending on their cultural background, users may focus on aspects concerning effectiveness, efficiency or satisfaction (or combinations of each) when using such products. Therefore, assuming there is a linkage between culture and attitude towards usability, products should be modelled to the user's local cultural background in terms of producing systems that accommodate user's cultural characteristics (Diehl & Christiaans, 2006).

At the School of Industrial Design Engineering, Delft University of Technology, the Netherlands a series of case studies have been initiated to explore cross-cultural design from the designer perspective. These case-studies are meant to gather as many examples as possible as to form a coherent view on what people moves, their experiences and, above all, the needs regarding their own responsibility in creating their own favourite environment. Current design methodology apparently is based on this object view also in tackling cultural diversity in product design. Starting from existing products, for instance designed for people in a western country, any need for adaptations in other cultures will be translated into adaptations to the existing product (see the case below). Another way is to offer a number of alternatives for the same product and to test people's preference. The design of a water purifier by a western company is an example of this strategy. People in India were offered a metal and a plastic one. For typical cultural reasons they preferred the metal purifier notwithstanding the higher price.

3.1 Case Study Influence of culture in consumer electronic products

In this study cultural differences were studied on the basis of a comparison between two cultures, the Netherlands and South Korea on design characteristics of consumer electronic products. People are not always aware of the influence of culture on their daily life. So, survey methods alone will not reveal their values and beliefs in relation to the material world. Therefore, a new method was developed to capture these culture related preference for the design and style of a product and its user interfaces. The method, called 'Design it yourself' method ('D.I.Y.'), makes it possible for the user to design the interface of his/her preferred microwave and washing machine. While expressing their own preference

during the test, it was believed that common attributes to their culture could be obtained.

The D.I.Y tool was a computer-based simulation of the microwave and the washing machine, made in Flash, with which the participant can move all separate parts (window, buttons, pictograms, and text) in order to design his/her favourite interface (see Fig. 8). Participants also had to choose a sound (out of 10), which is heard when a cooking program ends. Examples of microwave designs are presented in Figure 8. Analysis of the microwave interface designs shows differences between

Dutch and Korean people on a number of aspects: shape and arrangement of buttons, and the reason for their preference. Dutch participants preferred symmetry shape of button and symmetric arrangement while these were not the case with Korean participants. Both good-looking and usability were important to Dutch subjects while only the usability was most important to the Korean group. On the other hand, there were no differences on the size of buttons, indication, type of control, complexity on arrangement, and hierarchy.

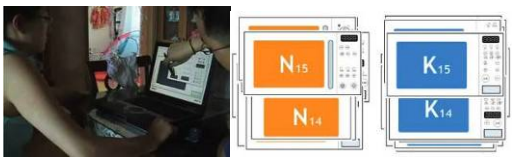

Figure 5: Participant using the Design-It-Yourself tool and the outcomes of the Dutch participants (N15) and the Korean participants (K15)

Use patterns were analyzed by looking at the displacement of the hand while operating the microwave on participant's designs. For this evaluation, a simple task was imagined, i.e. 'heating-up'. To do the task, people generally follow the sequence: watt control, time control, and start. Looking at the operation of Dutch participants three patterns, almost evenly distributed, were found: 'from top to bottom', 'going up and then down', 'going down and then up'. The patterns of the Koreans showed the distribution: 'from top to bottom', 'going up and then down', while the pattern 'going down and then up' did not appear at all. Differences were found in the choice of an 'ending' sound. Dutch participants did not show any uniform preference. Among the various reasons for their preference functionality of the sound was most frequently mentioned. Contrary the Korean group showed this uniformity. 'Nice to listen to' was the reason for this preference (Kim et al., 2006)

4. THE HUMAN NEED PERSPECTIVE

Talking about human product interaction the usual way to tackle this issue from a designer's point of view is the object perspective, followed by a market perspective. This view, which is taken for granted by economic rationalists, assumes that human beings are driven by a limitless craving for material possessions (Fisher, year unknown). The designed objects stemming from this way of thinking provide relatively specific, sometimes sophisticated offerings to a narrow range of people. However, in this view the human interest, needs and believes hardly play a role. Therefore an human need perspective should also taken into account, not by giving this issue only lip-service, offering the traditional western view of Maslow's hierarchy of needs (Maslow, 1962). This hierarchy doesn't exist apart from the basic need for subsistence or survival. Designing products for society within a perspective of social and cultural responsibility and commitment, should emphasize the promotion of emancipation, sustainable development, improvement of quality of life as well as the cultural identities of individuals and social groups. The author who takes a stance in the discussion about human needs is Max-Neef. His model of human-scale development can offer a breakthrough in our way of thinking about material culture.

4.1 The Max-Neef Model of Human-Scale Development

Max-Neef and his colleagues have developed a taxonomy of human needs. Human Scale Development is defined as "focused and based on the satisfaction of fundamental human needs, on the generation of growing levels of self-reliance, and on the construction of organic articulations of people with nature and technology, of global processes with local activity, of the personal with the social, of planning with autonomy, and of civil society with the state." (Max-Neef et al, 1987; p. 12)

Max-Neef et al. make an important distinction between needs and satisfiers. Human needs are seen as few, finite and classifiable (as distinct from the conventional notion that "wants" are infinite and insatiable). They are constant through all human cultures and across historical time periods. "What changes over time and between cultures is the way these needs are satisfied. It is important that human needs are understood as a system - i.e. they are interrelated and interactive " (Fisher, year unknown).

Max-Neef classifies the fundamental human needs as: subsistence, protection, affection, understanding, participation, recreation (in the sense of leisure, time to reflect, or idleness), creation, identity and freedom. Needs are also defined according to the existential categories of being, having, doing and interacting. From these dimensions, a 36 cell matrix is developed which can be filled with examples of satisfiers for those needs.

Fisher (year unknown) writes: "Max-Neef shows that certain satisfiers, promoted as satisfying a particular need, in fact inhibit or destroy the possibility of satisfying other needs: eg, the arms race, while ostensibly satisfying the need for protection, in fact then destroys subsistence, participation, affection and freedom; formal democracy, which is supposed to meet the need for participation often disempowers and alienates; commercial television, while used to satisfy the need for recreation, interferes with understanding, creativity and identity - the examples are everywhere. Synergic satisfiers, on the other hand, not only satisfy one particular need, but also lead to satisfaction in other areas: some examples are breast-feeding; self-managed production; popular education; democratic community organisations; preventative medicine; meditation; educational games."

This model forms the basis of an explanation of many of the problems arising from a dependence on mechanistic economics, and contributes to understandings that are necessary for a paradigm shift that incorporates systemic principles. Max-Neef and his colleagues have found that this methodology "allows for the achievement of in-depth insight into the key problems that impede the actualisation of fundamental human needs in the society, community or institution being studied" (Max-Neef et al, 1987:40)

This model provides a useful approach that meets the requirements of small group, community-based processes that have the effect of allowing deep reflection about one's individual and community situation, leading to critical awareness and, possibly, action al the local economic level.

Table 1: Taxonomy of human needs (Max-Neef et al., 1987)

Fundamental human needs	Being (qualities)	Having (things)	Doing (actions)	Interacting (settings)
subsistence	physical and mental health	food, shelter, work	feed, clothe, rest, work	living, environment, social setting
protection	care, adaptability, autonomy	social security, health systems, work	co-operate, plan, take care of, help	social environment, dwelling
affection	respect, sense of humour, generosity, sensuality	friendships, family, relationships with nature	share, take care of, make love, express emotions	privacy, intimate spaces of togetherness
understanding	critical capacity, curiosity, intuition	literature, teachers, policies educational	analyse, study, meditate, investigate,	schools, families, universities, communities,
participation	receptiveness, dedication, sense of humour	responsibilities, duties, work, rights	cooperate, dissent, express opinions	associations, arties, churches, neighbourhoods
leisure	imagination, tranquillity, spontaneity	games, parties, peace of mind	day-dream, remember, relax, have fun	landscapes, intimate spaces, places to be alone
creation	imagination, boldness, inventiveness, curiosity	abilities, skills, work, techniques	invent, build, design, work, compose, interpret	spaces for expression, workshops, audiences
identity	sense of belonging, self-esteem, consistency	language, religions, work, customs, values, norms	get to know oneself, grow, commit oneself	places one belongs to, everyday settings
freedom	autonomy, passion, self-esteem,, open-mindedness	equal rights	dissent, choose, run risks, develop awareness	anywhere

4.2 What does it mean for product design?

Creating products for people requires the understanding of the needs and context of the people within it. In this situation it is clear that researchers and designers should engage with cultures directly in order to better understand local people. A unique set of design and business tools and practices adapted from social anthropology, ethnography and participatory rural appraisal (PRA) should be used. This methodology will offer the ability to:

Engage in deep listening and mutual dialogue with income-poor communities.

Co-discover and co-create new product design opportunities and business models embedded in the local cultural infrastructure.

Co-design and launch products that generate mutual value for all partners.

5. CONCLUSIONS

Studying the consequences of cultural diversity for product design we are used to give priority to an designer perspective: how can we adapt products designed and manufactured in the western world to a global market; how can we increase product selling to a bigger population; what marketing strategies are effective? Even in the current research practice a new research vocabulary is 'invented', such as 'research through design', which give the impression that researchers and designers only have an eye for this kind of reasoning. This perspective leads to a reproduction of particular values, thereby maintaining the status quo and neglecting the real needs and satisfiers hold by people from different cultures. Therefore, another perspective is badly needed, one that emphasize the creativity of people in contributing to their satisfiers, the promotion of emancipation, sustainable development, improvement of quality of life as well as the cultural identities of individuals and social groups.

6. REFERENCES

[1] Christiaans, H., & Diehl, J.C., 2006. The importance of studying cultural diversity regarding product usability. In: R.N. Pikaar, E.A.P. Koningsveld, and P.J.M. Settels, eds. Proceedings IEA2006 Congress. Elsevier Ltd. 2006.

[2] Diehl, J.C. and Christiaans, H., 2007. Design for the base of the pyramid. In: EAD 07, Dancing with disorder: Design Discourse, Disaster. Izmir, Turkey.

[3] Dorst, K. (2008). The future cultures of Design. Keynote speech IASDR08 Conference. Hongkong.

[4] Fisher , K. year unknown. Max-Neef on Human Needs and Human-scale Development. http://www.rainforestinfo.org.au/background/maxneef.htm (consulted 20-12-2006)

[5] Foucault, B.E. and Russell, R.S., 2004. Techniques researching and designing global products in an unstable world: a case study. In: Dykstra-Erickson, E. and Tscheligi, M., eds. Proceedings of ACM CHI 2004 Conference on Human Factors in Computing Systems, Vienna, Austria.

[6] Hofstede, G., 1991. Cultures and organizations: software of the mind. London: McGraw-Hill.

[7] Kim, C.J., Christiaans, H.H.C.M. AND Diehl, J.C., 2006. Exploring the influence of culture in consumer electronic products. In: R.N. Pikaar, E.A.P. Koningsveld, and P.J.M. Settels, eds. Proceedings IEA2006 Congress. Elsevier Ltd. 2006.

[8] Laroche, L., 2003. Managing successfully across cultures. Boston, Butterworth-Heinemann.

[9] Mooij, M. de, 2004. Consumer behavior and culture. Consequences for global marketing and advertising. London: Sage Publications.

[10] Max-Neef, M., Elizalde, A. and Hopenhayn, M., 1987. Human scale development: Conception, application and further reflections. New York: Apex Press.

[11] Oo, M.M. (2005). Cultural diversity as a strategic source for designing pleasurable and competitive products, within the globalisation context. Journal of Design Research, 5 (1), 3-15.

[12] Trompenaars, F. and Hampden-Turner, C., 2002. Riding the waves of culture. 2nd ed. London : Nicholas Brealey Publishing.

Designing Stress Free Environments

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ABSTRACT

The goal of our studies is for designing less stress environment and equipment in product developments. For this purpose, we tried to design new forklift trucks that one comfortable for all operators. One way to do this is to design the operating elements so as to reduce fatigue and to improve the work efficiency of the operator. The steering wheel is one of the most important elements, and the recent trend is to make its radius smaller. However there are few reports about how the smaller radius affects fatigue on the operator.

Accordingly, basic research was done by multi-body dynamics analysis and EMG to compare a smaller radius steering wheel (130 mm) with the conventional one (150 mm) on an experimental apparatus. The subjects were 6 forklift truck operators, they are all Japanese males. The subjects' body movements were measured by motion capture system. The 3D marker data were aligned with the multi-body models by inverse kinematics analysis, and joint angles were calculated. The six axis force/torque sensor located on the steering knob was used to measure the operating force exerted by the subject's left hand. The joint torque was calculated by inverse dynamics analysis. 5 electromyograms on the left shoulder were used to measure muscle activity.

Results suggest that the smaller radius significantly decreases left shoulder joint torque in the steering angle range from 12 o'clock to 3 o'clock during counterclockwise rotation ($P<0.05$). These physiological analyses are very important in product developments.

1. INTRODUCTION

In the operation of a forklift truck, the left and right hands play different roles, with the left hand doing the steering and the right hand operating the lift. The optimum arrangement of the steering wheel and the lift lever is thought to strongly affect the usability of the truck and the reduction of fatigue on the operator. The conventional steering wheel has a radius of approximately 150 mm, but smaller steering wheels with a radius of around 130 mm have recently become more common. Telescopic steering columns and seat slide mechanisms have also been provided to adjust to the physical differences among operators.

Nevertheless, there were few reports that describe quantitative effects of smaller steering wheels and telescopic steering columns in reducing the fatigue on the operator. And few experimental data are available on such basic matters for design of how operators turn the steering wheel, what postures increase fatigue on the operator, and so on.

This article describes results of basic research on an experimental apparatus to establish the optimum steering wheel layout by using joint torque, operating force, and electromyograms (EMG). We evaluate the reduction of physical fatigue by a smaller steering wheel and telescopic slide for 6 subjects.

2. PROCEDURE

2.1 Experimental Setup

2.1.1 Experimental apparatus and steering unit

Fig. 1 shows the external appearance of our experimental apparatus. The apparatus is equipped with a steering wheel, seat, and accelerator pedal in the same layout as a conventional forklift truck. The steering reaction force is controlled by a DC motor.

Fig. 2 shows the steering unit that measures operating force. The unit contains the six axes force/torque transducer (ATI Nano25 SI-125-3 [1]) to measure the operating force that the subject exerts on the knob, and then uses a calibration matrix to convert the strain into translated forces in the X, Y and Z axis directions and the torques around each axis.

Also, because a knob on a conventional forklift truck has a mechanism that rotates around the Z axis, a rotating mechanism with built-in bearings was used for the knob on the steering unit. In addition, the steering radius can be varied by adjusting the positions of the knob and the counterweight.

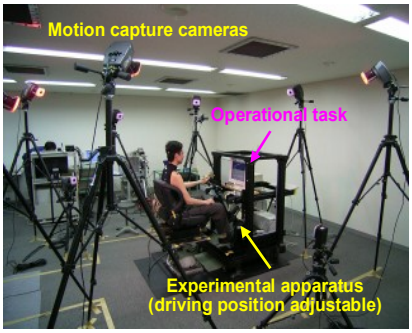

Figure 1: The experimental

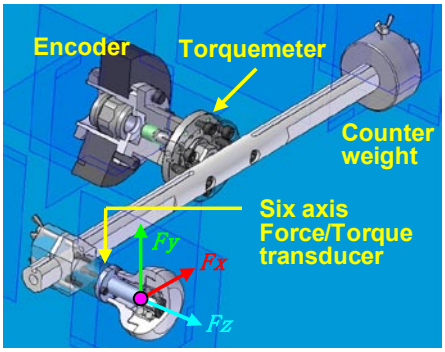

Figure 2: The steering unit for measuring operating forces and torques

2.1.2 Operational task

Fig. 3 shows the operational task of the experiment. In the task, the rotation angle of steering wheel is converted into horizontal movement of the cursor on the display screen. The task was to rotate the steering wheel at a constant velocity of 1 rps by keeping a white line within the cursor on the display.

The operating pattern was to rotate the steering wheel in one direction for 4 rotations, then rotate it in the opposite direction for 4 rotations. The operating time in one condition was 88 seconds (clockwise direction 32, counterclockwise direction 32 rotations).

2.1.3 Motion capture system and Multi-body model

The experimental apparatus and the subject were surrounded by 10 motion capture cameras (Motion Analysis Eagle [2]) to measure their movements during the operational task (see Fig. 1).

The multi-body model is our original. The model is composed of three rigid bodies of hand, forearm and humerus. Each joint of the wrist, elbow and shoulder has 6 degrees of freedom. Each model was made by adjusting constitution according to the physical features of each subject.

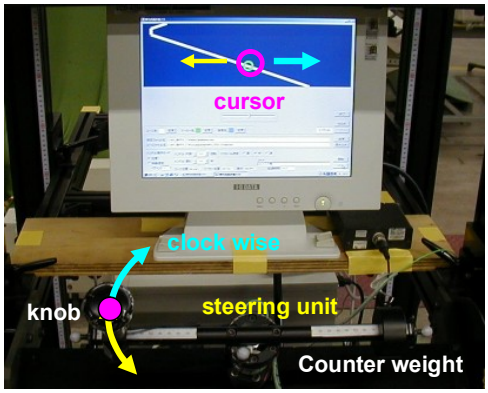

Figure 3: Operational task on PC display

2.1.4 Electromyogram

5 points EMGs were used to measure the activity of main muscles for the left shoulder movement. They are Pectoralis Major, Deltoideus Anterior, Deltoideus Middle, Deltoideus Posterior and Infraspinatus (It could reflect the activity of not only Infraspinatus but also Trapezius). EMGs were integrated every 0.1 seconds (iEMG), and normalized by maximum voluntary contraction (%MVC).

2.2 Experimental conditions

Table 1 and Fig. 4 show the experimental conditions. The control condition was set according to the layout of a conventional forklift truck, with steering wheel radius of 150 mm and no telescopic slide. For condition A, the radius was set to 130 mm. For condition B, the radius was set to 130 mm and a 30 mm telescopic slide to the subject side was added.

The neutral position of the steering knob was set around 9 o'clock from the viewpoint of the operator. In condition A and B, the neutral knob position was shifted for right side (20mm) compared to the control condition. In order to adjust the neutral knob position together, the seat was shifted 20 mm right side (the knob was shifted for 20mm left side) in condition A and B.

In the control condition, the subjects could adjust only the longitudinal position of the seat, using the accelerator (right foot) position as the reference point. In the condition A and B, the longitudinal position of the seat is same as the control condition.

Table 2 shows physical features of the 6 subjects. Their heights ranged from 158 cm to 183 cm, and they were all Japanese males who have a license for forklift trucks. In the experiment, subjects also described their impressions and feeling of fatigue.

Table 1: Experimental conditions

Experimental condition	Steering radius (mm)	Telescopic slide (mm)	Seat lateral slide (mm)
control	150	0	0
A	130	0	20
B	130	30	20

Table 2: The physical features of subjects

subject	JM1	JM2	JM3	JM4	JM5	JM6
Height (cm)	158	165	168	170	179	183
Weight (kg)	45	58	72	67	65	80
Age	40	30	41	37	34	35

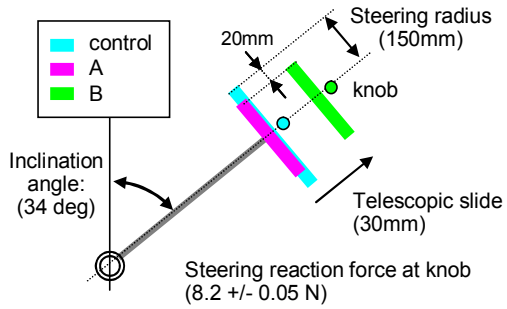

Figure 4: Experimental conditions from

3. ANALYSIS

3.1 Data processing

The recorded data were sampled at a frequency of 200 Hz. All markers that were measured by the motion capture system were converted into three-dimensional position data.

By the inverse kinematics analysis, the joint angles are calculated by alignment of measured markers with the markers set of the multi-body model. The angular velocity and angular acceleration of the joint angle are calculated by differential calculus (10th order Lanczos filter).

The gravitational, centrifugal and inertial force generated by the mass of the knob were canceled out of the forces that were measured by the steering unit, so that only the operating force exerted by the subject was acquired.

The Equation of motion for joint torque is shown in Eq. (1). The joint torque of the left shoulder, elbow and wrist were estimated by the inverse dynamics analysis. The equation of the resultant force vector of the shoulder joint torque is shown in Eq. (2). Fig. 5 shows an example of solving Eq. (1) by using measured force and motion data.

$$\underset{\text{Joint torque}}{\tau} = \underset{\text{Inertia force}}{M(q)\ddot{q}} + \underset{\text{Centrifugal force}}{H(q,\dot{q})} + \underset{\text{Gravity force}}{G(q)} + \underset{\text{Reaction force}}{J^T F} \quad (1)$$

$$\tau_{shoulder} = \sqrt{\tau_x^{\,2} + \tau_y^{\,2} + \tau_z^{\,2}} \quad (2)$$

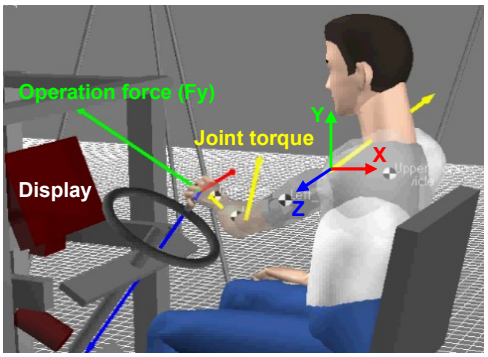

Figure 5: An example of solving Eq. (1) by using measured force and motion data

The operation was performed in one direction for 4 rotations. Data from the first rotation (the acceleration period) and the last rotation (the deceleration period) were excluded, and the middle two rotations at constant velocity were analyzed in each condition (clockwise direction: 16 rotations and counter- clockwise direction: 16 rotations).

All subjects reported that they felt the strongest physical load on their arm (shoulder) between 1 o'clock and 2 o'clock positions during counterclockwise rotation. This is the position at which the knob is farthest from the left shoulder and the wheel is being operated against direction from gravitational force, so the physical load on the left shoulder could be strong. Accordingly, the data were analyzed in the 12 o'clock to 3 o'clock range, and differences among the three conditions were compared.

3.2 Evaluation inddices

For the purpose of quantifying the physical workload during operation, a relationship was assumed to exist between the physical load and the absolute value of the force. So the evaluation indices were defined as the shoulder joint torque, which is the largest in the arm, and the EMG data.

There was variation in the actual rotation data. The 16 rotations' data for each direction were integrated, and then divided by the number of rotations. And the resulting mean value for 1 rotation (approximately 1 second) was used as a representative value for each condition. The mean

value of the shoulder joint torque was calculated as shown in Eq. (3). For the statistical processing, the paired t-test was used between two conditions.

$$T_{shoulder} = \frac{1}{N}\sum_{t=0}^{n}(|\tau_{shoulder}|)\Delta t \qquad (3)$$

4. RESULTS

4.1 Shoulder joint torque

Fig.6 shows changes in left shoulder joint torque (τ) during counterclockwise rotation of the steering wheel of subject JM4. These are results of a 7th order polynomial approximation by 16 rotations' measured data (the joint torque was fit for the steering angle). The "polyfit" command of MATLAB was used to estimate the coefficients of the function. The shoulder joint torque reaches its maximum between 2 o'clock and 3 o'clock position. The joint torque of other subjects also showed similar tendency.

Fig.7 shows a comparison of the average shoulder joint torques of the six subjects in the 12 o'clock to 3 o'clock range (The hatching part in Fig. 6). In condition A, the small radius steering wheel is used, the joint torque was decreased significantly compared to control condition (approximately 2.5%, P<0.05). In condition B, the 30 mm telescopic slide is added, the joint torque was decreased significantly compared to control condition (approximately 6.7%, P<0.01). However, there was no significant difference of the joint torque between condition A and B.

Fig.8 shows a comparison of the average gravity and the reaction force component of shoulder joint torque of six subjects. The gravity force components could be a major component of shoulder joint torque. In condition A, the gravity force component was decreased significantly compared to the control condition (P<0.01). In condition B, the gravity force component was both decreased significantly compared to control condition (P<0.01), and compared to condition A (P<0.05). On the other hand, the reaction force components were small and there were no differences among the three conditions.

Fig. 9 shows the changes of the τx, τy and τz components of the shoulder joint torque during counterclockwise rotation under control condition in subject JM4. The τy and τz components are remarkable. τy component reaches its maximum in the range from 12 o'clock to 3 o'clock. The τz component reaches its absolute maximum around 3 o'clock.

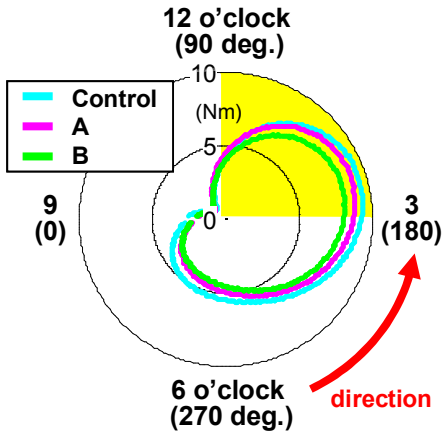

Figure 6: The changes in the shoulder joint torque during counterclockwise rotation (subject JM4)

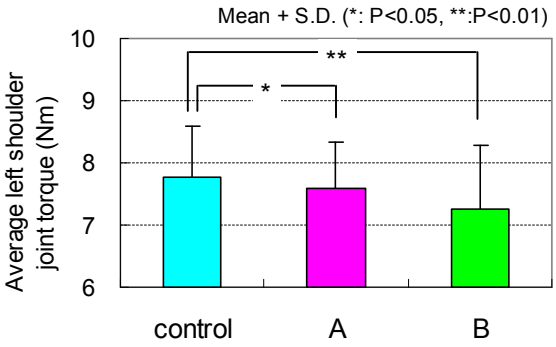

Figure 7: A comparison of the average left shoulder joint torques (τ) of the six subjects in the 12 to 3 o'clock range (The hatching part in Fig. 6)

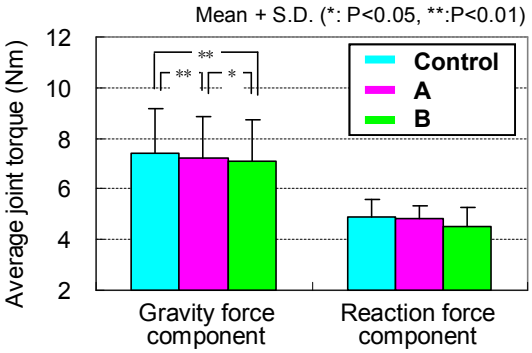

Figure 8: A comparison of the average gravity and reaction force components (in Fig. 7 data)

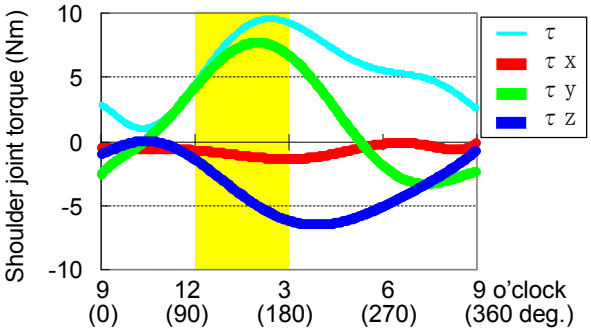

Figure 9: A changes of τ x, τ y and τ z component of the shoulder joint torque (τ) during counterclockwise rotation of steering wheel.

4.2 EMG

iEMGs of Deltoideus Middle, Deltoideus Posterior and Infraspinatus were analyzed, they are thought to be the main muscles of shoulder movement around the Y axis (τy) in the range from 12 o'clock to 3 o'clock during counterclockwise rotation.

Fig. 10 shows a comparison of the average iEMG data of the three muscles of the six subjects in the range from 12 o'clock to 3 o'clock. Especially, the activity of Infraspinatus was high.

There was no significant difference of iEMG of all muscles between control condition and condition A. In condition B, iEMG of Deltoideus Middle was decreased significantly compared to the control condition (approximately 20.5%, P<0.01). In condition B, iEMG of Infraspinatus was decreased significantly compared to the control condition (approximately 13.3%, P<0.05). And there was no significant difference of iEMG of all muscles between condition A and condition B. These results indicate the muscle load could be decreased by the combination of the smaller radius and the telescopic slide.

Fig. 11 shows changes in iEMG of Infraspinatus during counterclockwise rotation of subject JM4. The iEMG reaches its maximum around 2 o'clock. The iEMG of other subjects also showed a similar tendency.

4.3 Discussion

First, we consider possible causes of fatigue feeling around left shoulder in the 1 o'clock to 2 o'clock range, as reported in subjective evaluations. Shoulder joint torque (see Fig. 6), the τy of shoulder joint torque component (see Fig. 9) and iEMG of Infraspinatus (see Fig. 11) reach their maximum around the 2 o'clock position. Therefore, a fatigue feeling was affected by increased joint torque τy and its main muscle activity (especially Infraspinatus).

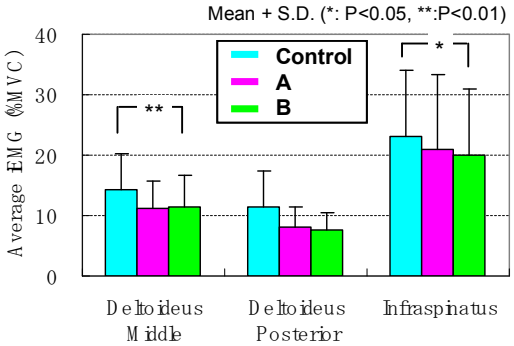

Figure 10: A comparison of iEMG of Deltoideus Middle, Deltoideus Posterior, and Infraspinatus in the range from 12 o'clock to 3 o'clock (N=6)

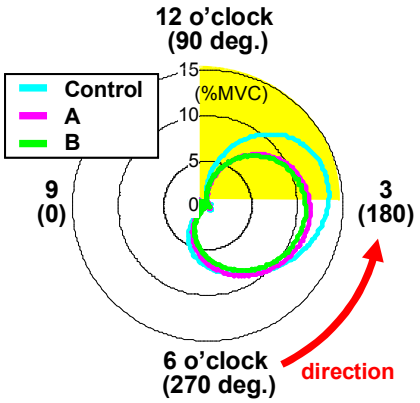

Figure 11: The changes in the iEMG of Infraspinatus during counterclockwise rotation (subject JM4)

Second, we consider effects of the smaller steering wheel radius and the telescopic slide function. Reducing only the steering wheel radius from 150 mm to 130 mm has an effect in reducing shoulder joint torque (see fig. 7). Adding the telescopic slide (30 mm) is thought to reduce not only joint torque but also the muscle load (see Fig. 10). Some reasons were guessed. In condition A, the center of gravity position of left arm was close to the left shoulder, decreasing of the gravity force components. In condition B, the center of gravity position was closer to the left shoulder than in condition A, that affect more decreasing the gravity force components (see Fig.8). So, the main reason for joint torque decrease was suggested as being the center of gravity position of the left arm was close to the left shoulder.

Either small steering or telescopic slide also was not effective for the muscle activity (see Fig. 10). However, the combination of small steering radius and telescopic slide brings the steering knob closer to the left shoulder, which would be expected to place muscles close to a natural length.

However, these results were limited on the Japanese males on an experimental apparatus, and we have to consider the operational condition of actual forklift trucks. Further studies under conditions close to an actual forklift truck are necessary in order to arrive at the comfortable layout of this operating system.

5. CONCLUSION

Results of the joint torque on the left shoulder indicated that the largest load is in the 12 o'clock to 3 o'clock range during counterclockwise rotation. The smaller steering wheel radius and telescopic slide have a possibility to reduce the joint torque and muscle load of the left shoulder, these effects were suggested quantitatively.

Our future plan is to study these effects in other portions of the rotation range and during clockwise rotation. It is also necessary to study the effect on the operator of steering wheel slide to the left side.

We believe these analyses are important for developing products that are focused on human centered design.

6. REFERENCES

[1] ATI Industrial Automation
http://www.ati-ia.com/products/ft/sensors.aspx

[2] Motion Analysis Corporation
http://www.motionanalysis.com/

Techno-adaptability

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ABSTRACT

The term 'techno-adaptability' is a coinage from 'technology' and 'adaptability'. There could be two definitions of it. The one is the human ability that acquires beneficial conditions for life maintenance by an increase in efficiency of social activities and a compensation for the limitation and disorder in physical functions with the assistance of technological support. To put it briefly, it could be mentioned as human adaptability using technology. For example, a natural climate of cold and heat environment which sometimes imperils our life maintenance has been conquered by development of clothing, housing and air-conditioning systems etc. And, humans can move much faster than their own proper physical capacity using motor vehicle or air plane. These products which were seemed as an additional organ to extend biological functions of humans could be called as 'exo-somatic organ', in contrast to 'endo-somatic organ' which is inherent in the human body. The one of the ultimate exo-somatic organs might be a computer which compensates information processing of human brain. On the other, 'techno-adaptability' would be defined as an ability which demonstrates any trait that maintains or improves biological functioning against new stresses originated from an intervention of technology to human's daily life. To put it briefly again, it could be mentioned as human adaptability to technology. Our ancestor had lived in natural environment during almost all times of their evolutional history. Therefore, human's body might be still adapted to natural environment. However, the environment where existent human beings are dwelling in developed country is quite different from natural environment. There would be constant controlled air temperature, bright lighting at night, a flood of information without regard to time and place, etc. These environments are full of stresses that cause a disorder of biological rhythm, visual and mental strain due to computer usage, increment of temporal and spatial pressure in congested city life etc. Such stresses are called as techno-stress. Study on techno-adaptability from both the two viewpoints described above has been anticipated to send useful information for creation of desirable living environment in the future.

1. INTRODUCTION

Human beings have prospered by technological civilization that has been brought by highly developed neo-cortex system of our selves. Such as clothing, housing, computer, transportation and communication systems etc, all are indispensable to our present living system. It goes without saying that the daily life without motor vehicles and cell phones is beyond our imagination no more. Furthermore, the day where newly developed artificial environment such as a space station become general would not be distant.

As described above, our present life environment has reached the stage which could not be made up without a support by scientific technology. Such kind of strategy for survival and prosperity might be thought to be proper for humans, which could not be seen in other organism. The development of technology enables us to protect ourselves from harsh natural environment and to obtain provisions securely, and increases life efficiency markedly. On the other hand, however, it has appeared that the artificial environment as a fruit of technology threatens not only human but other organism's survival. It is incompatible with their benefits that technology casts many serious problems on human beings such as destruction of the global environment, stresses of city life, less physical activity, overweight etc. Baker [1] described that there have been an interlocked process of adaptation and newly developed stress in the history of human evolution.

The word of techno-stress which was proposed in 1980s means physical and mental symptoms of a computer operator such as visual fatigue, low back pain, whole body tiredness, and so on. The definition of techno-stress, however, can be expanded as follows; not only the stresses owing to the inadequate human-machine interface, but also the stresses owing to the complexity of daily life system supported by highly advanced technology [2]. *Techno-adaptability*, one of the five keywords of physiological anthropology, suggests the relationship between human beings and technology with the background mentioned above.

2. TECHNO-ADAPTABILITY

The term '*techno-adaptability*' is the one of five keywords of physiological anthropology, including *environmental adaptability*, *functional potentiality*, *whole-body coordination* and *physiological polytypism*. Recently, these keywords have been the center of attention of physiological anthropologists, which suggest the way of approach to explore the human nature in physiological anthropology [3, 4] .

The meanings of these keywords are not independent each other, but they have hierarchical

and reciprocal interrelations. Among them, *environmental adaptability* shows a comprehensive view point of methodology in physiological anthropology. The term 'adaptability' here suggests the biological aspects involving evolution drawing a line with that of environmental physiology. *Techno-adaptability* has focused on human adaptability in artificial environment brought by science and technology in a sense of *environmental adaptability*. The meaning of *techno-adaptability* could be included in that of *environmental adaptability* in a broad sense. Therefore, the term '*techno-adaptability*' is not necessarily essential strictly. However, the fact that the term is particularly expressed as the one of keywords suggests the importance of approach to present life environment for existent humans in physiological anthropology. This aspect of *techno-adaptability* also demonstrates an expectation on social responsibility and contribution of physiological anthropology.

The term '*techno-adaptability*' is a coinage from 'technology' and 'adaptability'. That means peculiarities of human adaptability from a view point of cultural adaptation. At the present moment, there could be two definitions of *techno-adaptability* [5]. The one is the human ability that acquires beneficial conditions for life maintenance by an increase in efficiency of social activities and a compensation for the limitation and decline in physical functions with the assistance of science and technology. To put it briefly, it could be defined as human adaptability using technology. For example, humans have conquered a natural climate which cold and heat environment sometimes affects life maintenance by development of clothing, housing and air-condition systems etc. And, humans can move much faster than their own proper physical capacity using motor vehicle or air plane. These products which were seemed as an additional organ to extend biological functions of humans could be called an 'exosomatic organ', in contrast to 'endosomatic organ' which is inherent in human body.

On the other hand, *techno-adaptability* would be defined as an ability which maintains or improves biological functioning against newly developed stresses resulted from an application of technology in human's daily life. To put it briefly, it could be defined as human adaptability to technology. Our ancestor had lived in natural environment during almost all times of their evolutional history. Therefore, human's body might be thought to be still adapted to natural environment. However, existent human beings dwelling in developed country live in an environment which is quite different from natural environment; constant controlled air temperature, bright lighting during night, a flood of information without regard to time and place, etc. These environments are full of stresses that cause a disorder of biological rhythm, visual and mental strain due to computer usage, increment of temporal and special pressure in congested city life etc. Study on human adaptability to such stresses from an application of technology has been anticipated to send useful information for production of desirable living environment in the future.

In this brief review, *techno-adaptability* defined as the latter is discussed with reference to our recent works.

3. APPROACH TO TECHNO-ADAPTABILITY

3.1 Relationships among the Five Keywords

Interrelationships among the five keywords including *techno-adaptability* should be understood, when *techno-adaptability* is examined. The five keywords of physiological anthropology indicate the way to elucidate the substances of human adaptability [5]. Figure 1 shows the methodology of physiological anthropology which shows a hierarchical relationship among the five keywords. The two keywords, *whole-body coordination* and *functional potentiality,* suggest the way of analyses of physiological mechanisms of human reaction to various environmental stressors at an individual level. In the field of physiological anthropology, various physiological functions are measured in a well-controlled laboratory setting. In a case if the various physiological functions are perceived as independent phenomena, the biological function or significance cannot be understood or else there is likely to be a large possibility that a mistaken interpretation and understanding of such phenomena may occur. From the view point of physiological anthropology, physiological functions are coordinated in order to achieve the biological functioning as an individual. For example, human bipedalism is accomplished by a coordination of agonist and antagonist leg muscle contractions, neuro-muscular systems and a central nervous system with sensory feedback. This way of analyses of physiological functions is presented in a keyword of *whole-body coordination*.

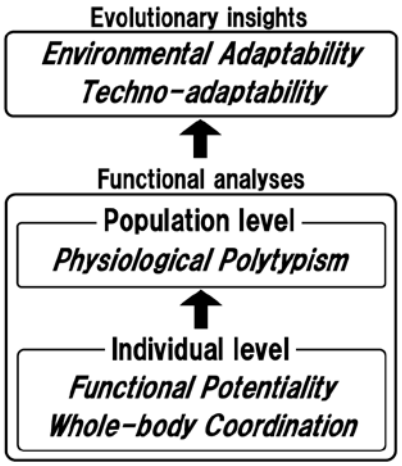

Figure 1: Structure of the methodology of physiological anthropology; Hierarchical relationship among the five keywords.

Human physiological functions show the plasticity meeting the environmental demand. It is well known that physical work capacity improves by habitual physical training, and on the other hand, muscle mass and its contraction force decreases easily by disuse. This plasticity of physiological functions is considered as a principle of physiological adaptability at an individual level. Physiological anthropologists make a point of this plasticity of physiological functions in relation with environmental factors, though genetic background is duly considered. This way of insight of physiological functions is presented in a keyword of *functional potentiality.*

Physiological anthropology is based on the viewpoint of studying human behavior as being based on physiological functions mentioned above. These biological functions, based on behavioral physiological mechanisms, produce some useful effect for the organisms. Thus, as a result, they are perceived as being a form of 'adaptation.' When considering the above, it is only natural and quite understandable that such key words of physiological anthropology as *environmental adaptability* and *technological adaptability* are used.

The accomplishment of a biological function of a behavior-based physiological mechanism is a form of adaptation. Thus, it is not possible to ignore the wide variations of these forms of adaptation in relation to environmental factors. In other words, the question of whether the behavior-based physiological function is beneficial depends on its relationships with environmental factors. Therefore, it is inevitable that the observed physiological phenotype shows variations in relation with living environment. This is expressed as *physiological polytypism*.

Physiological polytypism, as the various phenotypes of human physiological reactions, is used to refer to the existence of many different types of physiological phenotypes that exist within a given group. In a classic study of physiological anthropology, it was shown that there are two different types of cold tolerance, the one is the type of enhanced heat production and the other is that of enhanced insulation with much lower skin temperature [6].

These diversities of physiological phenotype could be considered as a result of different aspect of *whole-body coordination* and *functional potentiality* in relation with the environmental and genetic factors. The human physiological reaction as a phenotype consists of interaction between multiple physiological mechanisms (*whole-body coordination*). And within these multiple physiological mechanisms, some mechanisms are observable and some are not observable. However, in the process of adaptation, the non-observable mechanisms change to become observable and form a new biological function (*functional potentiality*).

Based on many different environmental factors, the changes in content of *whole-body coordination* and *functional potentiality* can be perceived as physiological mechanisms of *environmental adaptation* that represent useful changes for survival in a given environment.

3.2 Physiological Adaptability to Intellectual Mental Stresses

The author and co-workers have been studying the physiological adaptability to mental stresses using the methodology of physiological anthropology. The reason why we investigate mental stresses is that mental stresses and physiological reactions to them show a biological trait unique to human beings. Mental stresses could be divided into two different types, emotional and intellectual [7]. Emotional mental stress gives arise to physiological strain resulting from instinctive or intuitive feelings, which is generated in the limbic system and is partly common to humans and many animals. On the other hand, intellectual mental stress gives arise to physiological strain resulting from sophisticated information cognition and processing in humans, which is generated by the neo-cortex system interconnected with the limbic system. Therefore, intellectual mental stress could be seen as a model of stresses which is generated in a modern society, and a study of adaptability to it could be one approach to *techno-adaptability.* Furthermore, the comparison of physiological reaction to both type of stresses provide useful information about human mind evolution.

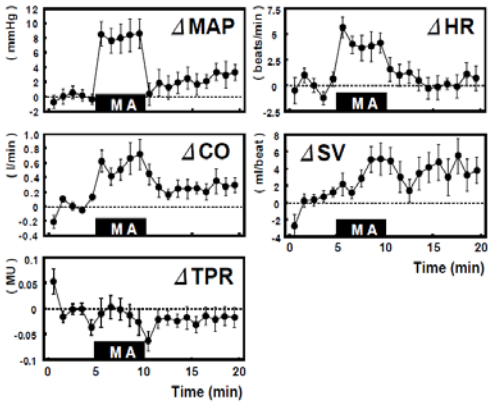

Figure 2: Changes in MAP, CO, TPR, HR and SV during mental arithmetic (subtraction) task (MA). Values are means and SE of 10 subjects.

In the experiment, we measure cardiovascular reactions mental arithmetic task as an intellectual stress [2, 8, 9]. Figure 2 shows the changes in mean arterial pressure (MAP), cardiac output (CO), total peripheral resistance (TPR), heart rate (HR) and stroke volume (SV) during mental arithmetic (subtraction) task. Values shown in the figure are means of 10 subjects. As shown here, MAP increased markedly during mental subtraction task.

Other indices except for TPR also show increases, although TPR does not show definite trend in change at averages of subjects.

Change in blood pressure reflecting activity of autonomic nervous system has been often used as a physiological measure of stress response [10, 11, 12, 13]. From the view point of *whole-body coordination*, however, it is not sufficient to measure the only one index to explore *physiological polytypism*. Though how to observe *physiological polytypism* has been discussing, different pattern of combination of changes in several physiological parameters at an individual level would be a criterion of *physiological polytypism* from the view point of *whole-body coordination* and *functional potentiality*. In our study, changes in CO and TPR both which contribute the change in blood pressure are considered to observe *physiological polytypism* in cardiovascular reaction to mental stress [2, 8, 9].

Figure 3 shows changes in CO and TPR during mental subtraction task in different two subjects [2]. As shown here, subject A showed an increase both in CO and TPR (Figure 3, left column). On the other hand, subject B showed a decrease in TPR even though CO increased (Figure 3, right column). Although almost all subject tested showed an increase in AMP as a reaction to mental subtraction task, there were different types of contribution on it in CO and TPR reactions. The responses of CO and TPR to mental subtraction task of 40 subjects were examined [9]. An increase both in CO and TPR were observed in 24 subjects (peripheral contributors, PC), while an increase in CO and a decrease in TPR were observed in 14 subjects (peripheral non-contributors, PNC). A decrease in CO was observed, though an increase in TPR was seen, in 2 of 40 subjects.

Described above, it could be considered that there are different types of cardiovascular reactions to mental intellectual stress at a population level. However, it is needed to discuss the biological significance of the difference in reaction pattern from the view point of adaptation in order to approach *techno-adaptability* or *environmental adaptability*.

Mazess [14] suggested that "the essence of environmental adjustments deemed adaptive seems to be that they are considered relatively advantageous, beneficial, or meritorious, or that they are to a degree necessary." Therefore, relative benefit or merits of the physiological trait should be considered when the observed physiological phenotype is interpreted as adaptive or not.

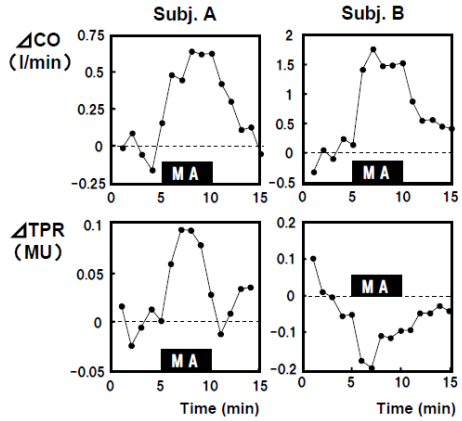

Figure 3: Changes in CO and TPR in two subjects. MA shows mental arithmetic task periods for 5 minutes.

Many previous studies reported that increase in blood pressure observed in a laboratory stress test could reflect the higher risk of further essential hypertension and other cardiovascular diseases [15, 16]. In our study, the comparison of MAP rise during mental subtraction task between PC and PNC revealed that PC showed significantly higher MAP rise than PNC. Therefore, PNC could be treated as more adapted group to intellectual mental stresses.

Described above, human adaptability to intellectual activities could be examined according

to the methodology of physiological anthropology. However, even if the two different types of physiological phenotype to intellectual stress have established, the biological origin of them remains to be solved at a population level. Mainly with focus on the reactivity of blood pressure, a difference in reactivity to laboratory stress tests has been studied from numerous different viewpoints, including socio-economic status [17, 18], immigrant acculturation [9, 19, 20, 21], medical history of family (in terms of hypertension) [22], sex difference [23, 24], heredity [23, 25], and personality [26].

4. CONCLUSIONS

As described above, the methodology of physiological anthropology is constructed by the five keywords, including *techno-adaptability*. So, the expression of *techno-adaptability* could be demonstrated by human variation of adaptability to modern life.

Based on the methodology of physiological anthropology, the new design concept is needed to be constructed. In the concept of universal design, it is promoted to share a system with various people having different attributes. However, it is not always needed to be the same system even if to achieve the common goal of the people. This idea would expand the concept of universal design. Today, concern for the elderly and disorders should not be avoided in design activities. However, it should be noted that there are various differences of physiological traits in healthy and ordinary people on the surface.

The conclusions of this brief review are summarized as follows:

1) The methodology of physiological anthropology could be a powerful way to explore the diversity of humans living in modern society.

2) Human intellectual activity prompts several physiological responses which could be considered as human adaptability to techno-stress.

3) Building the conceptual framework of design based on the methodology of physiological anthropology is needed to meet the diversity of humans and their life style.

5. ACKNOWLEDGMENTS

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5. REFERENCES

[1] Baker, P. T. (1984). The adaptive limits of human populations. *Man* 19(1):1-14.

[2] Iwanaga, K., Liu, X. X., Shimomura, Y., Katsuura, T. (2005). Approach to human adaptability to stresses of city life. J. Physiol. Anthropol. Appl. Human Sci. 24(4): 357–361.

[3] Sato, M. (2005). The development of conceptual framework in physiological anthropology. J. Physiol. Anthropol. Appl. Human Sci. 24(4): 289–295.

[4] Iwanaga, K. (2005). The biological aspects of physiological anthropology with reference to its five keywords. J. Physiol. Anthropol. Appl. Human Sci. 24(3): 231-235.

[5] Iwanaga, K. (2006). Introduction of techno-adaptability; Human adaptability through technological development. Abstract Book of the 8th International Congress of Physiological Anthropology. 22-23.

[6] Scholander, P. F. (1958). Studies on man exposed to cold. Fed. Proc. 17(4): 1054-1057

[7] Iwanaga, K. (in press). Human Adaptability to Emotional and Intellectual Mental Stresses: in Human Variation: From the laboratory to the Field, edited by N. Mascie-Taylor and Rie Goto, SSHB series vol 48.Boca Raton: Taylor & Francis.

[8] Liu, X. X., Iwanaga, K., Shimomura, Y., Katsuura, T. (2007). Comparison of stress responses between mental tasks and white noise exposure. J. Physiol. Anthropol. 26(2): 165-171

[9] Liu, X. X., Iwanaga, K., Shimomura, Y., Katsuura, T. (2007). Comparison of stress responses between mental tasks and white noise exposure. J. Physiol. Anthropol. 26(3): 355-364.

[10] Bongard, S., Pogge, S.F., Arslaner, H., Rohrmann, S., Hodapp, V. (2002). Acculturation and cardiovascular reactivity of second-generation Turkish migrants in Germany. J. Psychosomatic Res. 53:795-803.

[11] Eliasson, K., Hjemdahl, P., Kahan, T. (1983) Circulatory and sympatho-adrenal responses to stress in borderline and established hypertension. J. Hyperten. 1:131-139.

[12] Gregg, M. E., James, J. E., Matyas, T. A., Thorsteinsson, E. B. (1999). Hemodynamic profile of stress-induced anticipation and recovery. Inter. J. Psychophysiol. 34:147-162.

[13] Lawler, K. A., Kline, K. A., Adlin, R. F. (2001). Psychophysiological correlates of individual differences in patterns of hemodynamic reactivity. Int. J. Psychophysiol. 40:93–107

[14] Mazess, R. B. (1975). Biological adaptation: aptitudes and acclimatization. In *Biosocial interrelations in population adaptation,* ed. E. S. Watts, F. E. Johnston , and G. W. Lasker, 918-927. The Hague:Mouton Publishers

[15] Flaa, A., Eide, I.K., Kjeldsen, S.E., Rostrup, M. (2008). Sympathoadrenal stress reactivity is a predictor of future blood pressure: an 18-year follow-up study. Hypertension 52 (2):336-341

[16] Matthews, K. A., Owens, J. F., Kuller, L. H., Sutton-Tyrrell, K., Lassila, H. C., Wolfson, S. K. (1998). Stress-induced pulse pressure change predicts women's carotid atherosclerosis. Stroke 29:1525-1530

[17] Steptoe, A., Feldman, P. J., Kunz, S., Owen, N., Willemsen, G., Marmot, M. (2002). Stress responsivity and socioeconomic status. Eur. Heart J. 23:1757-1763

[18] Steptoe, A., Magid, K., Edwards, S., Brydon, L., Hong, Y., Erusalimsky, J. (2003). The influence of psychological stress and socioeconomic status on platelet activation in men. Atherosclerosis 168: 57-63

[19] Cruz-Coke, R. (1987). Correlation between prevalence of hypertension and degree of acculturation. J. Hypertens. 5:47– 50.

[20] Hackenberg, R.A., Hackenberg, B. H., Magalit, H. F., Cabral, E. I., Guzman, S. V. (1983). Migration, modernization and hypertension: blood pressure levels in four Philippine communities. Med. Anthropol. 7:45–71

[21] Hull, D. (1979). Migration, adaptation, and illness: a review. Soc. Sci. Med. 13A: 25–36.

[22] Lawler, K. A., Kline, K., Seabrook, E., Krishnamoorthy, J., Anderson, S. F., Wilcox, Z. C.,et al. (1998). Family history of hypertension: a psychophysiological analysis. Int. J. Psychophysiol. 28:207-222

[23] Cheng, L. S-C., Carmelli, D., Hunt, S. C., Williams, R. R. (1997). Segregation analysis of cardiovascular reactivity to laboratory stressors. Genetic Epidemiology 14:35–49

[24] Sabban, E. L. (2007). Catecholamines in stress: molecular mechanisms of gene expression. Endocr. Regul. 41(2-3):61-73

[25] IJzerman, R. G., Stehouwer, C. D. A., Boomsma, D. I. (2000). Evidence for genetic factors explaining the birth weight–blood pressure relation analysis in twins. Hypertension 36:1008-1012

[26] Habra, M. E., Linden, W., Anderson, J. C., Weinberg, J. (2003). Type D personality is related to cardiovascular and neuroendocrine reactivity to acute stress. J. Psychosomatic Res. 55:235–245

Driver Distraction, Secondary Visual Task Load, and Attention-Related Abilities

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ABSTRACT

In this study, the ability of three attention-related psychological tests to predict the amount of driver distraction, caused by a secondary task not related to driving, was investigated. The three tests were as follows: 1) A test for measuring visual divided attention capability (Useful Field of View test, or UFOV); 2) A test for measuring task-switching ability (TSA-IAT), and 3) A self-designed task for measuring a person's ability for (visual) controlled processing, called Complex Visual Search (CVS). Driver distraction was measured using a standardized PC-based tool, called the Lane Change Task (LCT). A visual search task, imposing either a low or a high demand on the driver's visual processing capacity, served as secondary task to be performed simultaneously with the (primary) driving task (LCT). Results of an experiment using 20 subjects showed that, as expected, both secondary tasks were significantly distracting in an overall sense. In addition, UFOV- and TSA-IAT-performance significantly predicted the driver's baseline driving performance (without distracting secondary task) in the expected direction. However, contrary to expectation, high UFOV-performance also significantly predicted a large amount of distraction caused by the complex visual (secondary) task. CVS-performance was only weakly related to any LCT-based performance measure. Potential explanations and applications of these results will be offered.

1. INTRODUCTION

Attentional problems are estimated to account for 5 - 25 % of all car accidents (Young, Regan, & Hammer, 2003; Pettitt, Burnett, & Stevens, 2005). According to a recent white paper about the future of the field of traffic safety, driver attention and distraction are estimated to be the most important human factors research issues of the coming years with the potential of directly affecting traffic safety (AAA Foundation for Traffic Safety, 2006).

Obviously, when driving, not all types of distraction can be avoided. Therefore, driver psychology becomes important as a means to find out how drivers can be selected or trained to be prudent users of such potentially dangerous technologies.

In this article we investigate the role played in driver distraction by three attention-related abilities. Specifically, we study the extent to which the scores on tests for measuring these abilities can be used to predict the amount of distraction experienced by the same drivers when performing a secondary visual task while driving a car in a driving simulator.

2. PROBLEM STATEMENT AND HYPOTHESES

2.1 Psychological tests

The three tests and the corresponding abilities are as follows:

Test for *Useful Field of View* (UFOV) (PC-based version), subtest 3: Useful Field of View is defined as the visual area in which one can extract useful information without eye or head movements (sometimes also called simply *Functional Field of View* or FFOV). Subtest 3 is the most complex subtest of the UFOV which measures, in addition to divided attention ability, aspects of central processing speed and of selective attention (Ball & Owsley, 1993).

Test of *Task-Switching Ability* (TSA), using the paradigm of an *Implicit Association Test* (IAT): test is assumed to measure a person´s ability to switch between task sets (Back, Schmukle, & Egloff, 2005), an ability often associated with attentional (or executive) control and with general intelligence (Duncan et al., 1996).

A task for *Complex Visual Search* (CVS): a self-designed task used to measure the ability of a person to detect a conjunction-type visual target presented in an array of visual distractors. The task is based on Ackerman (1988) and is assumed to require a type of "controlled processing" related to general intelligence.

For some of these abilities (e.g., UFOV) it is known (or likely) that they are age-sensitive (Ball, Roenker, & Bruni, 1990), older drivers having less of these abilities than younger drivers do. Therefore, in this study we will also look in an exploratory sense at age effects in both test scores and amount of driver distraction.

In this study, driver distraction was induced by two secondary tasks. The first secondary task is an easy visual task (imposing a low visual load on the driver). The second secondary task is a complex

visual task (imposing a high visual load on the driver), requiring mainly controlled processing.

2.2 Hypotheses

Based on the literature, we decided to test the following hypotheses:

1. Performing either secondary task is distracting in an overall sense, but performing an easy visual secondary task is less distracting for the primary driving task than performing a difficult visual secondary task. *(Confirmation is required in order to be able to test hypotheses 2, 3, and 4.)*

2. The higher the performance on the UFOV, the better the driver is able to combine a visual secondary task with the primary driving task, and, hence, the smaller the amount of driver distraction caused by the secondary task.

3. The higher the performance on the TSA-IAT, the better the driver is able to combine a visual secondary task with the primary driving task, and, hence, the smaller the amount of driver distraction caused by the secondary task.

4. The higher a person's CVS-score, the smaller the amount of mental load experienced by the person, and, hence, the less distracting it is for that person (as a driver) to timeshare a complex visual secondary task with the primary driving task.

2.3 Approach

Distraction was measured using a standard methodology called the *Lane Change Task* (LCT; Mattes, 2003). Using this instrument, distraction is measured by having subjects perform a lane-keeping task (LCT) with a high degree of realism both *with* (dual-task condition) and *without* (single-task condition) a distracting secondary task. The difference between the two LCT-performance scores obtained under these conditions is taken as the measure of the amount of distraction caused by the secondary task.

For practical reasons, we decided to use the complex visual secondary task of our study also as the test for measuring a person's CVS-score. That is, the answers given by our subjects to the secondary task questions were recorded and scored in order to obtain the CVS-score (see *Method* section for details).

3. METHOD

3.1 Subjects

Eleven male and 9 female drivers in the age range of 19-62 years of age participated in this experiment. Through a background questionnaire subjects were asked about their Driving Exposure (average number of rides per week), Driving Experience (cumulative license duration in months), and their age (in years). The experiment lasted about 50-60 minutes and subjects received a reward of €7 or 2 credit points (if subjects were students) for their participation.

3.2 Equipment and Instructions

Divided attention ability was measured with the PC-based version of the *Useful Field of View* test (UFOV), subtest 3. The UFOV ran on a Pentium 4 Dell PC with a standard 17 in monitor. The test was administered in a dimly lit room. For each subject, the software automatically computes the shortest presentation time (in ms) at which an average accuracy of 75 % is obtained. This time is used as the subtest score (higher values indicate worse performance).

The second standardized test was the TSA-IAT (TSA, for short), providing an indication of an individual's *Task-Switching Ability*. The TSA was translated from German into Dutch and implemented in E-prime. It was also run on the Pentium 4 Dell PC mentioned above. In the test, a centrally presented item must be classified as quickly as possible on each trial. Regularly (but at unpredictable times) subjects have to switch from a numerical classification task (choosing between "numbers" and "arithmetic expressions") to an alphabetical classification task (choosing between "words" and "letters"), depending on the type of central item to be classified. Two categories are combined on each side.

On two blocks of trials the combined categories are semantically compatible (e.g., numbers and arithmetic expressions). On two other blocks the same-side categories are incompatible (e.g., numbers and letters). Compatible trials always followed the incompatible trials. The difference between the mean reaction times for compatible and incompatible trials is assumed to be indicative of a person's task-switching ability (the higher the score, the worse the task-switching ability). In this study, the D_1 measure suggested by Back, Schmukle, and Egloff (2005) was used for computing the TSA-score: the difference in reaction times computed for a person is expressed as a fraction of the standard deviation of all reaction times obtained for that person.

The participants driving skills were measured with the *Lane Change Task* (LCT) (Mattes, 2003). The LCT ran on a Pentium 4 Dell PC equipped with a special graphics card. The road image generated by the LCT was projected on a wide (42 in diameter) TFT LCD monitor. Subjects were seated in an authentic car seat with the LCT-screen at eye height, controlling the LCT using a game steering wheel and foot pedals. The distance between the

subject's face and the centre of the wide monitor was about 1.70 m. For each experimental condition subjects completed one track, corresponding to a straight road segment of 3 km.

At irregular intervals 18 switch-signs were presented in a random order on both sides of the road, instructing the subject to move to one of the three road lanes (left, right, or middle) (see Figure 1). The indicated lane was always different from the current lane. After switching, subjects were required to keep their car in the middle of the new lane as much as possible. Driving speed was always held constant at 65 km/h. LCT-performance on any track was calculated off-line by LCT-analysis software and was expressed as the average amount of deviation (in meters) between a normative model and the actual driving course (see Figure 1).

A secondary visual task was presented during LCT-performance on two of the four tracks. The remaining two tracks were baseline (control) tracks on which no secondary task was performed. The secondary task consisted of either a simple or a difficult visual search task. Both visual tasks were programmed in E-prime and ran on a Pentium 4 Dell PC using a 19 in flatscreen, positioned on the left-hand side of the LCT-monitor at a 30° viewing angle. On each trial of the simple visual task (V1, feature search) subjects were to name the deviating color (red or green) in which one of 17-19 blue cross symbols was rendered on the screen.

In the complex visual task (V2, conjunction search) subjects were presented with 9 or 10 crosses and 9 or 10 circles on each trial, randomly displayed on the screen. Crosses were always rendered red and circles were always rendered blue (or the other way around) except for one symbol. Subjects were to name the shape (cross or circle) of the symbol with the deviating color.

For both visual tasks trials were presented at fixed intervals of 5 s. The complex visual task was also used for measuring each individual's *Complex Visual Search* (CVS) ability (expressed as % correct answers). Subjects' answers to the secondary task questions were spoken out loud and typed in on the PC-keyboard by the experimenter. This was done in order to be able to measure CVS-performance.

3.3 Procedure

When participants arrived for the experiment, they were first asked to fill out an informed consent form and a background questionnaire. Next, they were instructed to complete either the UFOV or the TSA depending on which block they were assigned to. Participants were then familiarized with the driving simulator driving one track without secondary task while receiving instructions from the experimenter. After the learning phase, subjects had to drive the first control track (C1), followed by the two secondary task tracks, and with a second control track (C2) presented at the end of the sequence. Each visual secondary task started with 6 practice trials familiarizing the subjects with the task without performing the LCT. After the last LCT-track, the subject completed either the UFOV or the TSA, whichever had not been completed yet.

3.4 Design and analysis

The experimental design was counterbalanced with respect to the sequence in which the two secondary tasks (V1 and V2) were presented and with respect to the order of presenting the UFOV and the TSA. However, the LCT-tracks were always presented in between the two tests. As recommended by the LCT-manual, two baseline LCT-tracks were used, C1 and C2, presented at the beginning and at the end of the sequence of LCT-tracks, respectively. This resulted in the four blocks (sequences of presentation) indicated in Table 1. The twenty subjects were evenly and randomly assigned to these four blocks.

Hypothesis 2-4 will be tested using multiple regression analysis with the scores on the UFOV, TSA and CVS as independent variables, and the LCT-deviation-difference scores as dependent variables. LCT-deviation-difference scores were computed by subtracting each person's LCT/CON-score (average LCT-deviation score obtained on the two control tracks) from that person's LCT/V1-score or, alternatively, from that person's LCT/V2-score (LCT-deviation score obtained on the secondary task tracks). GLM repeated measures analysis was used to test the difference between the LCT-scores obtained on control (single-task) tracks and on secondary task (dual-task) tracks (Hypothesis 1).

Table 1: Sequences of presentation used for the various tests and experimental conditions.

1	UFOV	LCT/C1	LCT/V1	LCT/V2	LCT/C2	TSA
2	TSA	LCT/C1	LCT/V1	LCT/V2	LCT/C2	UFOV
3	UFOV	LCT/C1	LCT/V2	LCT/V1	LCT/C2	TSA
4	TSA	LCT/C1	LCT/V2	LCT/V1	LCT/C2	UFOV

***Note*:** Subjects were evenly and randomly assigned to these four sequences. For explanation of abbreviations used, see text.

4. RESULTS

Table 2 contains descriptive statistics of the LCT-performance variables, the psychological test variables, and three demographic (background) variables (Driver Age, Driving Experience, and Driving Exposure). The LCT-variables are broken down according to the type of secondary task performed simultaneously with the LCT: no secondary task (LCT/C1 and LCT/C2), easy visual secondary task (LCT/V1), and complex visual secondary task (LCT/V2).

It can be seen that, on the average, subjects were 33 years of age, had 8.5 years of driving experience, and made a little over 2 rides per week.

The average UFOV-score that was observed (160 ms) represents an average-to-good visual divided attention ability (based on the diagnostic categories mentioned in the UFOV-manual).

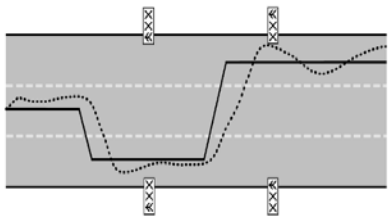

Figure 1: Schematic overview of Lane Change Task. Car approaches from the left. Solid line represents normative model for switching and driving behavior, dotted line represents actual behavior.

The average TSA-score obtained (0.72) indicates that the difference between a person's average reaction time for the incompatible trials and that for the compatible trials is about 72 % the size of the standard deviation of all reaction times for that person. Finally, the average CVS-score (79 % correct) indicates a rather high accuracy in answering questions requiring complex visual search.

4.1 Distracting effects of secondary tasks (Hyp. 1)

In Table 2 it can be seen that the average LCT-deviation score is about 20 cm higher for the easy secondary task (V1, 1.74 m) than for the baseline conditions C1 and C2 (average score 1.54 m). In addition, it is about 30 cm higher (1.85 m) for the complex secondary task (V2). GLM repeated measures analysis, using type of secondary task as independent variable, shows the effect of secondary task level to be statistically significant, $F(2,38) = 13.99$, $p < 0.001$ (C1 and C1 collapsed into one level). Post-hoc comparisons reveal that all levels are significantly different from each other, $p < 0.05$, except the difference between V1 and V2, $p = 0.10$. These results did not depend on the specific value of UFOV, TSA, Driving Exposure, Age, and CVS (non-significant interactions between type of secondary task and covariate scores).

We conclude that Hypothesis 1 is partly confirmed in that there is an overall distracting effect of performing a secondary visual task on the primary driving task. However, it is not confirmed in that the complex secondary task was not significantly more distracting than the easy secondary task.

4.2 Predictive value of test scores (Hyp. 2-4)

For exploratory purposes, a first multiple regression analysis was conducted with LCT/CON (average of LCT/C1 and LCT/C2) as dependent variable. The results are presented in Table 3. The regression of LCT/CON on the three test scores (UFOV, TSA, CVS) is significant, $F(3,16) = 3.61$, $p < 0.05$, and has an R^2 value of 0.40. In other words, 40 % of the variance in LCT/CON scores can be explained by the three test scores.

Of the test scores, UFOV and TSA have significant regression coefficients, $t(16) = 2.79$ for UFOV and $t(16) = 2.32$ for TSA, both p's < 0.05, respectively: the better the test performance, the better the LCT-performance (standardized coefficients equal 0.62 for UFOV and 0.47 for TSA).

Table 4 shows the regression analysis results for LCT/(V2-CON) (difference between LCT/V2 and LCT/CON). The regression of this variable on the three test scores (Table 3) is not significant and has an R^2 value of only 0.24. The regression coefficients of the test scores are only significant for UFOV, $t(16) = -2.14$, $p < 0.05$, standardized coefficient equals -0.54. However, contrary to expectation, the regression coefficient for UFOV turns out to be negative, rather than positive: the higher the UFOV-performance, the *larger* the amount of distraction caused by V2!

The regression analysis for LCT/(V1-CON) (difference between LCT/V1 and LCT/CON, not shown in tables) was not significant either and did not have significant regression coefficients.

In summary, neither of Hypotheses 2, 3, and 4 was confirmed. However, the LCT-baseline deviation score was significantly predicted by UFOV and TSA in the expected direction. In addition, the LCT-deviation score for the complex secondary task was significantly predicted by UFOV, but in a direction opposite from expectation.

Table 2: **Descriptive statistics for LCT-deviation scores, psychological test scores, and demographic variables.**

Variable	Mean	Standard deviation	Variable	Mean	Standard deviation
LCT/C1	1.51	0.30	TSA (D_1)	0.72	0.24
LCT/C2	1.57	0.27	CVS (% correct)	78.94	11.54
LCT/V1	1.74	0.39	Driver age (in years)	32.80	13.10
LCT/V2	1.85	0.23	Driving experience (cumulative license duration in months)	102.95	120.45
UFOV	159.94	84.53	Driving exposure (average number of rides per week)	2.15	0.93

Note: Driving Exposure coded as 1 (for 0 or 1 rides per week), as 2 (for 2 rides per week), or as 3 (for 3 or more rides per week). All numbers based on 20 observations (subjects). LCT-scores expressed as the average deviation in meters. UFOV and TSA represent error scores (the higher the score, the worse the performance).

Table 3: Outcomes of regression analysis for LCT/CON. TSA-scores multiplied by 100 before entering the analysis.

Predictor/ Component	Unstand. coefficient	Stand. coefficient	SS	df	MS	R^2	F	t	p
Regression			0.50	3	0.17	0.40	3.61		0.037
Error			0.74	16	0.05				
Intercept	0.660							1.34	0.200
CVS	0.003	0.13						0.59	0.560
UFOV	0.002	0.62						2.79	0.013
TSA	0.005	0.47						2.32	0.034

Table 4: Outcomes of regression analysis for LCT/(V2-CON). TSA-scores multiplied by 100 before entering the analysis.

Predictor/ Component	Unstand. coefficient	Stand. coefficient	SS	df	MS	R^2	F	t	p
Regression			0.26	3	0.086	0.24	1.67		0.214
Error			0.83	16	0.052				
Intercept	1.270							2.44	0.027
CVS	-0.007	-0.33						-1.37	0.190
UFOV	-0.002	-0.54						-2.14	0.048
TSA	-0.002	-0.24						-1.06	0.307

5. CONCLUSIONS AND DISCUSSION

The conclusions of the experiment reported in this article can be summarized as follows.

First, both visual secondary tasks were distracting in an overall sense: the LCT-deviation scores observed under dual-task conditions were significantly higher than the ones observed under single-task conditions (LCT-baseline performance). Though the complex visual task (V2) was more distracting than the simple one (V1), the difference between the two dual-task conditions was only marginally significant.

Second, both UFOV- and TSA-performance predict LCT-baseline performance quite well. Though these predictions were not hypothesized, they indicate that under normal driving conditions (no secondary task), cognitive processes related to divided (visual) attention and task-switching ability are necessary to complete the driving task successfully. Moving the steering wheel, paying attention to the lane one is trying to keep, and paying attention to the switch-sign are complex tasks demanding a wide variety of cognitive functions, even though attention is paid to only one monitor.

Third, the effect of UFOV just mentioned may also reflect an effect of age: UFOV-performance declined with age, as did LCT-baseline performance. More research is needed

to identify the precise role played by age in explaining LCT-baseline performance.

Fourth, contrary to expectations, better UFOV-performance predicted a *larger* amount of distraction caused by the complex secondary task (V2) (negative regression coefficient in Table 4). This was true, even after the result had been corrected for effects of age, driving experience and driving exposure. This finding is both puzzling and fascinating. One explanation is that UFOV-performance is not related at all to LCT-performance under dual-task conditions. Indeed, post-hoc data analysis revealed a very low correlation between UFOV-performance and LCT-performance when the LCT is timeshared with V2. This low correlation may be caused by the larger visual field used under dual-task conditions: subjects now have to move their head and eyes to switch their attention between two monitors. Perhaps different types of attentional processes are needed under these circumstances, not measured by UFOV. This might be an issue to be investigated by future research. Given this finding and the finding of a positive correlation between UFOV-performance and LCT/CON (see Table 3), the negative correlation mentioned above makes perfect sense from a mathematical point of view, for the amount of distraction caused by V2 is calculated by subtracting LCT/CON from LCT/V2, resulting in *larger* amounts of distraction for persons having a higher UFOV-performance.

Fifth, neither TSA nor CVS were found to be predictive of the amount of distraction caused by either V1 or V2. Neither did UFOV predict the amount of distraction caused by V1. Apparently, V1 was too simple a secondary task to cause the type of distraction that can be predicted easily by psychological tests such as the ones used in our study.

Sixth, a significant negative correlation was also observed between age and CVS-performance: the older the person, the lower CVS-performance, again indicating age-related decrement. However, age did not seem to have an impact on the amount of distraction caused by V1 or V2. The precise role played by age in predicting attention-related abilities and in predicting the amount of driver distraction caused by secondary tasks remains an issue for future research.

Finally, in this study Complex Visual Search performance was not measured independently of the LCT, but, for practical reasons, was measured using the complex visual secondary task, which was performed simultaneously with an LCT-track. Because our subjects may have had different timesharing strategies, they also may have paid different amounts of attention to the CVS-task. Therefore, it is hard to know how useful the CVS-task has been in this study as a measure of controlled processing on which subjects show reliable individual differences. Future research should take up this issue and try to replicate this (or a similar) experiment using a more reliable and more valid measure of CVS.

6. REFERENCES

[1] Young, K., Regan, M., & Hammer, M. (2003). *Driver Distraction: A Review of the Literature.* Monash University Accident Research Centre.

[2] Pettitt, M., Burnett, G., & Stevens, A. (2005). Defining driver distraction. Paper presented at *World Congress on Intelligent Transport Systems,* San Francisco, November.

[3] AAA Foundation for Traffic Safety (2006).*Traffic safety issues of the future: a long range research agenda*. January, 2006. Washington, DC: AAA Foundation for Traffic Safety.

[4] Ball, K. & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association, 64,* 71-79.

[5] Back, M.D., Schmukle, S.C., & Egloff, B. (2005). Measuring Task-Switching Ability in the Implicit Association Test. *Experimental Psychology,* 52(3), 167-179.

[6] Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: the organization of goal-directed behavior. *Cognitive Psychology, 30*(3), 257-303.

[7] Ackerman, P.L. (1988). Determinants of individual differences during skill acquisition: Cognitive abilities and information processing. *Journal of Experimental Psychology: General, 117*, 288-318.

[8] Ball, K., Roenker, D., & Bruni, J. (1990). Developmental changes in attention and visual search throughout adulthood. In Enns, J. (Ed.), *The Development of Attention: Research and Theory.* North Holland: Elsevier Science Publishers, 489-508.

[9] Mattes, S. (2003). The lane change task as a tool for driver distraction evaluation. In H. Strasser, H. Rausch, & H. Bubb (eds.), *Quality of work and products in enterprises of the future.* Stuttgart: Ergonomia Verlag

A human centered collaborative design methodology

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ABSTRACT

This human centered collaborative design methodology aims to help companies to innovate by integrating human factors in the design of products and the associated production means. The objective is to help the actors involved in a design process to make design choices during the decision-making process, which respect the needs and characteristics of the future users.

We will explain how this methodology can stimulate to improve the usability of design solutions, within the context of a specific design project. Studies, ergonomic analysis and integration of the human factor are described, which can be undertaken during each phase of the design process from a design methodology based on concurrent engineering. During the feasibility phase, real activity analysis tools are used for analysis of similar or existing products. During the preliminary phase, gesture and postural activity are simulated with a digital human model. Virtual reality is used for evaluation of the product with real users during detailed study. And a real prototype is validated with representative users during the industrialization phase.

These representations of the user-product-environment system contribute to a dialogue between the different actors in the design process, specifically between the ergonomist, design engineer and the future user. This assures integration of the human factor. The methodology has been validated by several experimentations involving various companies.

1. INTRODUCTION AND OBJECTIVES

Today, the economic environment is characterized by strong competition, which puts companies under a lot of pressure. To survive this worldwide competition, they are forced to shorten delivery times, to decrease prices and to improve product quality and variation, and to produce increasing volumes with increasing production speed. This pressure influences product development.

As result of time saving in product development, designers tend to underestimate aspects such as the integration of human factors. The result is that many products which surround us have not been designed to be a response to end user expectations, such as the need for usability [1]. Usability represents the ease to use and to learn to use a product. Indeed, it corresponds to the capability of the device to be used easily and rapidly, by a given person, in order to achieve the task for which this object was designed [2]. We come across products intended for the general public, which remain complex [3][4].

There is also increasing pressure to reduce the cost price while retaining quality. This pressure on companies is likely to increase the pressure on workers [4]. Workplaces, as part of manufacturing systems, can be inadequate and cause serious health problems. This lack of human factor consideration in the design process is thus one of the multiple causes of work related risks and injuries, particularly of the most known which are Musculoskeletal Disorders (MSD), a set of disorders resulting from the accumulation of microtraumatisms caused by in particular mechanical constraints of repetitivity, excessive force, extreme postures and extreme joint articulations, resulting in an overload of the nerves, tendons, muscles in term of amplitude and force [5]. Thus, in order to stay competitive and innovative on the long term, companies must change their design and production process and integrate the human factor into their procedures [3].

In context of company competitiveness, an answer can be found in Design for Usability (DFU) [6] or Design for Ergonomics (DFE) [7], which are included in Design for X (DFX), a set of product development techniques which can be applied to the design process to make it more effective [8].

Several design methodologies have been developed, which aim to integrate the human factor in product development by participation and representation of the end user in the design process. Specifically for assemblage production means, TNO, the Netherlands Organisation for Applied Scientific Research, follows a participatory and integrative design approach [4]. Duchamp [9] developed an approach based on the articulation of ergonomics and design engineering in which the ergonomist plays a role as co-designer. Quarante [10] introduces a methodology to integrate

ergonomics into the design process. Two parallel processes, ergonomics and design engineering, interact by exchanges that are made between the ergonomist and designer throughout the whole design process. The ergonomist has here the role of counselor. Bobjer and Jansson [11] propose a methodology, which is orientated specifically on the design of production means and hand tools. It is composed of a sequence of stages and characterized by analysis of tasks, users and environments within which the new product will be used and by strong user participation in the design process.

Starting from this articulation of design engineering and ergonomics, our human centered collaborative design methodology follows a multidisciplinary approach [12]. It is based on concurrent engineering, that is to say the parallelization of multidisciplinary tasks in the design process. It aims to help companies to innovate by integrating human factors in the design of products and the associated production means. The objective is to provide methods and simulation tools for product usability definition and optimization that can help the actors involved in a design process to make design choices that respect the needs and characteristics of the future users. The methodology is based on classical design engineering phases, but integrates studies and ergonomic analysis that can be undertaken during each phase of the design process. For study and simulation of the human-product-environment system, during four complementary phases, either real or virtual representations of human, product and environment are used.

The methodology stimulates collaboration between the ergonomist, design engineer and end user as different actors in the design process. This is important for human centered optimization as well of the ease of implementation of design solutions [13].

In the following sections, we will explain how this methodology can stimulate to improve the usability of design solutions. We will start with an explanation of the methodology in detail, then describe its application to the redesign of a work station, discuss the results of this specific design project and conclude with perspectives for further development of the methodology.

2. METHOD

In this section, we will detail more precisely the different phases of the methodology developed by Sagot et al. [12]. The methodology is visualized in figure 1. In every phase, human, product and environment are represented either in real or in virtual form. The relation between the ergonomist and the design engineer is illustrated by two complementary triangular surfaces, in which the X-axis represents time and the Y-axis degrees of freedom for each specialism [14].

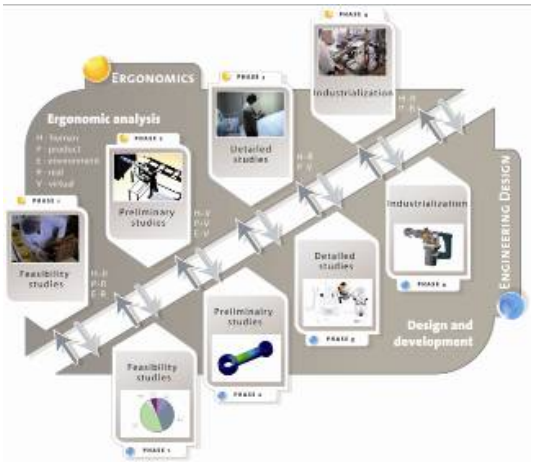


Figure 1: Human centered collaborative design methodology [12].

Table 1: Ergonomic evaluation and design tools which are used in the four consequent phases.

Phase 1	Questionnaires, evaluation form (APACT [16]), task and activity analysis (KRONOS [17]), cognitive ergonomic tools (like Stroop Effect and Double Task Test), posture analysis (RULA [18]), physiological and biomechanical measurements
Phase 2	Digital human model with ergonomic evaluation tools, CAD
Phase 3	Virtual reality platform, CAD
Phase 4	Real prototype, a selection of ergonomic evaluation tools of phase 1

This indicates that an ergonomic intervention is easier and less expensive in the earlier phases of the design process, because concepts still in development are easier to change then a prototype [15]. For each phase, the tools which can be used are shown in table 1.

1.1 Phase 1 – Feasibility studies

The first phase is used to identify the need, to study the market and the design project feasibility. The ergonomist follows a classical ergonomic approach to analyse the real activity in the existing situation or in similar situations. The real activity is objectively and clearly analysed by the ergonomist to gain insight in the users' needs and behaviour and to identify ergonomic problems. The studied system is here completely real. The ergonomic study is composed of two parts. In the first part, the global analysis, a diagnosis of the

activity is made according to different ergonomic aspects (cognitive, physical, emotional, organizational etc.) by use of different tools (real-time observation, discussion, provoked explanation method, etc.) and several tools like observation forms. The second part, the deepened analysis, consists of evaluation of the aspects determined as problematic during the global analysis, by help of a set of tools, chosen according to the data coming from the global diagnosis. Table 1 shows examples of specific tools which are used during these two sub-phases. One of the objectives of this approach is to be able to distinguish the difference between the prescribed task (what is asked from the operator) and the activity that is performed by the operator in reality. Frequently, differences are observed between what should be done to use the work station and which actually is done. These differences can cause usability problems with the production mean. The ergonomist gives ergonomic recommendations to be integrated in the specifications. The ergonomic analysis of the real activity can, in this way, help the design engineer to define the first design orientations.

1.2 Phase 2 – Preliminary studies

In the second phase, concepts are developed by the design engineer with CAD, based on the specifications. The ergonomist now plays the role of counsellor and actively participates to the concept definition, by checking the integration of use related aspects. Gesture and postural activity are simulated with a digital human model, in which an anthropometric database and postural, visual, energetic and biomechanical evaluation tools and movement evaluation tools are integrated. These simulations allow the ergonomist to make suggestions for the definition and the choice of the final concept. The studied system now consists of a virtual human, virtual product and virtual environment. To define the concepts, iteratively evaluations with the digital human model are done and modifications in CAD are made. In the end of this phase, a final digital concept is validated by the multidisciplinary project team.

1.3 Phase 3 – Detailed studies

During detailed studies, the chosen digital concept is developed and optimized regarding the specifications (technical feasibility, production, material choice, material resistance, structure calculation etc.). Then, a digital prototype is realised that integrates this set of criteria. The ergonomist continues to accompany the design engineer by tests on the digital concept with digital human models, but also by virtual reality. A virtual reality platform, consisting of 3 large screens (2,10m x 2,80m) with stereoscopic visualization, data gloves and an optical system of movement capture, allows studying the concepts still in digital state. During this phase, we study the system with a real human and a virtual product. The chosen design solution is evaluated by potential users and by the other actors in the design process, while it is still in virtual state. The project actors can check expectations and correct problems that had not appeared in preceding phases. In virtual reality the future activity a variety of use scenario's can be simulated by letting interact the potential users with the virtual concept. For example, a digital human model which shows the prescribed activity can be included, the chosen concept can be compared with the current situation or with other concepts, or certain parameters, like dimensions or colours can be changed for evaluation.

The VRADU (Virtual Reality Aided Design for Usability) methodology [3] describes usability evaluation of the digital concept in virtual reality. It proposes three design activities using virtual reality as a tool, which can all together or separately help integration of the human factor in the design proposal. During qualitative ergonomic analysis of the product and associated use, all concerned design actors are immersed in virtual reality and discuss the virtual prototype, but there is no interaction with the prototype. During quantitative ergonomic analysis of the product and associated use, the end user is immersed in virtual reality and interacts with the virtual prototype, while the ergonomist is only immersed in virtual reality, observing and analyzing the behavior of the end user. For example, this can be helped by real-time ergonomic evaluation tools in virtual reality like NIOSH, developed by Aptel et al. [19] and implemented in virtual reality by Chryssolouris et al. [20] or RULA, developed by McAtammey et al. [18] and implemented in virtual reality by Jayaram et al. [21]. During the design of the virtual prototype and the associated use, the design engineer is immersed in virtual reality and interacts with the virtual prototype make real-time changes, while the other design actors are immersed in virtual reality and observe and discuss this interaction.

The feedback from the tests in virtual reality is used to optimise the CAD model of the final concept. This evaluation and optimization cycle can be repeated several times.

1.4 Phase 4 - Industrialization

Once the digital concept has been developed according to all product aspects (functional, manufacturing, ergonomics etc.), in the industrialization phase, a physical prototype is realized for evaluation validation in reality by tests

with representative users. The system now consists of a real human, real product, and a virtual or real environment. At this stage, despite all precautions, it is usual still to observe differences between the theoretically defined activity and the real functioning of the operator facing the physical prototype. In fact, the realized physical prototype cannot correspond completely to the real functioning of the future operators. It is therefore still necessary to add modifications and corrections. Finally, the product goes through a phase of final validation before it is industrialized. Then, the ergonomist uses the classical tools of evaluation again to study the first real products.

3. APPLICATION AND RESULTS

The described methodology has been validated by several experimentations involving various industry partners. In this section, the methodology will be illustrated by examples of how ergonomic evaluation and design tools have been used during the redesign of a work station in a cheese production company (figures 2a and 2b). In this case, ergonomic evaluation and improvement was asked of some of the workstations of a new packaging line, but not of the complete line. The project team existed of a design engineer, an ergonomist, three operators which worked on the existing work post, and the production line manager.

1.5 Phase 1 – Feasibility studies

Before redesign of the workstation, the existing situation has been analyzed by means of several tools. Two examples are described in the following paragraphs.

For example, APACT sheets [16] are used for a global analysis of work conditions and organization of the existing situation. Each aspect is judged, based on a number of predefined parameters on a scale of 0 to 10. A note above 6,5 means that the aspect is acceptable (green aspects in figure 3). Figure 3 shows which aspects, in this case, need to be corrected or improved. Individual autonomy, monotony, product handling, social environment and mental demands of the station are indicated as very problematic.

Figure 2a and 2b: Photos of the existing work station. a: Closing a box. b: Stamping a box.

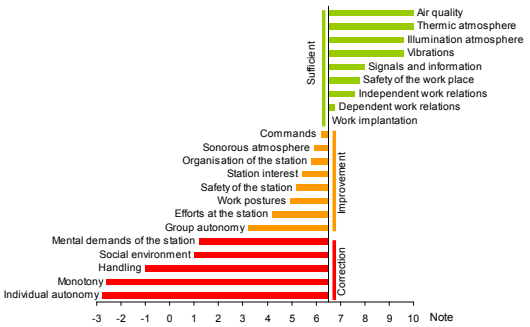


Figure 3: APACT diagram.

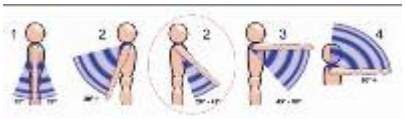


Figure 4: Example of RULA angle determination.

Table 2: RULA action levels.

Action level 1	Acceptable posture if not maintained or repeated for long periods
Action level 2	Further investigation needed, may require changes
Action level 3	Further investigation needed, changes required soon
Action level 4	Further investigation needed, changes required immediately

A second example is the application of the Rapid Upper Limb Assessment (RULA) algorithm [18], which enables angle and effort based posture evaluation (figure 4). The outcome knows four "action levels" (table 2). This is used after the global analysis, to determine more precisely the physical ergonomic factors from the APACT diagram (figure 3), like in our example, product

handling, work postures and efforts at the station. Both postures shown in figures 2a and 2b are indicated with "action level" 3. When closing a box, risks are located at the wrists, probably due to the strict alignment which is needed in a narrow box with upstanding borders. When stamping, risks are located at neck, trunk and under arm.

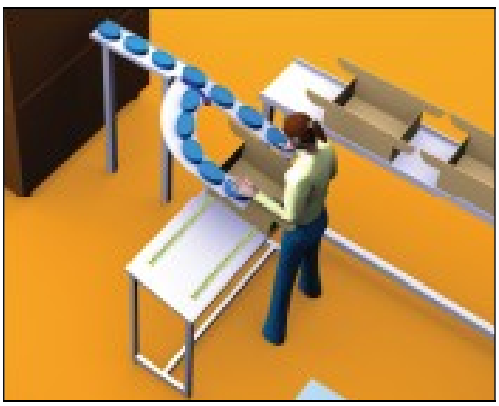
In this paper, related to our choice to use the application of RULA as example, we especially described the evaluation of physical ergonomic factors. Other problematic ergonomic factors for this work station have been studied with tools which are not described in this paper.

1.6 Phase 2 – Preliminary studies

With the aim to improve the detected ergonomic problems, several concepts have been developed. The finally chosen concept is shown in figure 5a. Simulation and ergonomic evaluation with digital human models (figures 5b and 5c) have helped the project team to draw ergonomic conclusions and to choose a concept.

The work posture of the operator has been improved in several ways. The products arrive in front of the operator, within the field of view, by two separated distribution lines for each hand. The box is placed on an inclined plan close to the body, which improves the accessibility of the box and the line of vision, and in reaction to this, the posture of the operator.

The concept provides improvement in several other ways as well. Transportation distance of full product boxes has been reduced. The operator has a good vision on the whole packaging line. The space around the work station enables better communication between operators. And to improve autonomy of the operator, a buffer is built in.



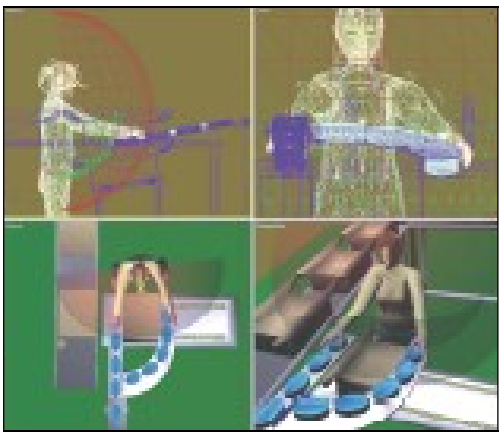


Figure 5a, 5b and 5c: a: The digital CAD model with digital human model. b: Evaluation of field of view by different point of views. c: Continuous RULA evaluation of gesture simulation.

1.7 Phase 3 – Detailed studies

To get feedback of the real users, the production line manager and three operators who normally work on the redesigned work station, have been immersed in virtual reality, in which they interact with the chosen concept. These operators, the design engineer and the ergonomist gave qualitative feedback in virtual reality. Thanks to the immersion in virtual reality, and the realistic scale of the concept, especially remarks about physical aspects of the interaction with the work station were rapidly and spontaneously given (figure 6a). Remarks were for example, that the work plane was placed too high and too far from the operator.

These remarks have been used to optimize the CAD model of the final concept on technical, organizational, ergonomic and social aspects. This evaluation and optimization cycle can be repeated several times. Thanks to the feedback, the design solution can be ergonomically optimized when it is still in virtual state, before a real prototype is built. A digital concept can still easily be changed, which

saves time and money. The number of corrections to the physical prototype can be reduced. Furthermore, integration of future users in the design process and implementation of user feedback into the design is important for acceptation of the new work station by the operators [13].

1.8 Phase 4 – Industrialization

Figure 6b shows the prototype of the new work station. For evaluation, this prototype is analyzed while a real operator is working with it, with help of several real activity analysis tools. Given that RULA is used as example tool to illustrate this study, we will compare the RULA results of the prototype and the existing situation. This shows that the prototype is evaluated with «action level» 2 (table 2) for several different postures, compared to «action level» 3 for the postures in the existing situation (figures 2a and 2b). This indicates that improvement is gained on MSD risks.

Evaluations of this kind can bring additional information related to product implementation and safety. The last optimizations can be done before industrialization is started.

Figure 6a and 6b: a: Immersion of an operator in virtual reality. b: The new work station.

4. CONCLUSIONS AND PERSPECTIVES

By the use of the described set of tools (APACT, RULA, 3D digital human model, CAD, virtual reality platform, physical prototype), this human centered collaborative design methodology can help companies to innovate by integrating human factors in the design of products and the associated production means. We propose to apply this design methodology in order to guarantee ergonomic redesign of work stations. It can advise the different actors in the design process for taking into account human factors when making design choices, and it contributes to a dialogue between all the different actors in the design process. In particular, it stimulates an intensive cooperation between the ergonomist and the design engineer.

In general, physical ergonomics are easier to be objectively measured and evaluated, because they are very specific and directly related to physical design aspects, in contrast to psychological and emotional factors, which are more difficult to detect or describe. In the digital human model, physical, physiological and sensorial aspects (vision) are now integrated. An interesting question remains, how to integrate evaluation of psychological and social aspects in the digital human model. In virtual reality, interaction between the potential user and the digital human model(s) might enable evaluation of social aspects.

The impressiveness of the virtual reality experience, as well as the visually highly finished prototype presentation, might cause hesitation to give critical feedback. To reduce this effect, a short introduction training is given to get used to the virtual reality experience, before starting the prototype evaluation.

By the use of virtual reality, a reduction of the number of physical prototypes can be realized, and potential users can give detailed qualitative feedback early in the design process. But, as stated in the method description, neither the virtual prototype nor the physical prototype can correspond completely to the real functioning of the future operators. Therefore, evaluation and validation in the real future situation will always be necessary. Nevertheless, immersion in virtual reality as well as interaction with the physical prototype can stimulate potential users to give qualitative feedback that can be reliable and specific enough to base optimizations on.

To be able to use the set of tools more efficiently, we are still developing this methodology by adding (automated) ergonomic evaluation tools to the virtual reality platform, to make ergonomic aspects directly visible for all actors in the design process. Next to this, we are going to add industrial design as a third dimension to this methodology, to complement ergonomics and design engineering.

5. REFERENCES

[1] Nielsen, J. (1994). Usability Engineering. Published by Morgan Kaufmann, San Francisco, 362 p.

[2] Brangier, E. & Barcenilla, J. (2003). Concevoir un produit facile à utiliser. D'Organisation (Editions), 261p.

[3] Mahdjoub, M.., Gomes, S., Sagot, J.C. & Bluntzer, J.B. (2007). Virtual Reality for a human-centered design methodology. 6th Eurosim (federation of European simulation societies) congress on modelling and simulation, September 9 - 13, 2007, Ljubljana, Slovenia.

[4] Van Rhijn, J.W., De Looze, M.P., Tuinzaad, G.H., Groenesteijn, L., De Groot, M.D. & Vink, P. (2005). Changing from batch to flow assembly in the

production of emergency lighting devices. International Journal of Production Research, 43(17), 3687-3701.

[5] Putz-Anderson, V. (1988). Cumulative Trauma disorders: a manual for musculoskeletal diseases of the upper limbs. London, Informa Healthcare.

[6] Nieminen, M. (2004). Information support for user-oriented development organization - Considerations based on the construction and evaluation of knowledge storage. Doctoral dissertation, Helsinki University of Technology, Espoo, Finland, 237p.

[7] Allada, V., Kopardekar, P., Anand, S. & Mital, A. (1992). Implications of ergonomic and user considerations on manufacturing consumer, in: DE Flexible Assembly Systems. Proceedings of the Fourth International Conference on Design, Theory and Methodology, September 1992, Scottsdale, AZ, pp. 25-33.

[8] Huang, G.Q. & Mak, K.L. (1997). The DFX shell: a generic framework for developing design for X tools. Robotics & Computer-Integrated Manufacturing, 13(3), 271-280.

[9] Duchamp, R. (1988). La conception des produits nouveaux. Editions Hermes, Paris, 60p.

[10] Quarante, D. (1994). Eléments de design industriel. Polytechnica, Paris, 645p.

[11] Bobjer, O. & Jansson, C. (1997). User participation in hand tool design. Proceedings of Ergonomics in the design, use and selection of hand tools, Sheffield, pp. 9-15.

[12] Sagot, J. C., Gouin, V. & Gomes, S. (2003). Ergonomics in product design: safety factor. Safety Science, 41(2-3), 137-154.

[13] Vink, P., Koningsveld, E.A.P. & Molenbroek, J.F.M. (2006). Positive outcomes of participatory ergonomics in terms of greater comfort and higher productivity. Applied Ergonomics, 37(4), 537-546.

[14] Duchamp, R. (1999). Méthodes de conception de produits nouveaux. HERMES Science Publications, Paris, 192 p.

[15] Mahdjoub, M. (2007). La réalite virtuelle pour une conception de systèmes mécaniques centrée sur l'utilisateur. Doctoral dissertation, University of technology of Belfort-Montbéliard, 6 December 2007, 180 p.

[16] APACT (1991). Guide d'évaluation des conditions et organisations du travail. Association de la prevention et de l'amélioration des conditions de travail. Published by APACT, Paris, 35p.

[17] Kerguelen, A. (1997). The Kronos software: a tool for work activity analysis. Proceedings of 13th Triennal Congress of international Ergonomics Association, Tempere.

[18] McAtammey, L. & Corlette, E.N. (1993). Rapid Upper Limb Assessment (RULA): a survey method for the investigation of work related upper limb disorder. Applied Ergonomics, 24(2), 91-99.

[19] Aptel, M. & Dronsart, P. (1995). Charge maximale admissible de lever de charge, l'équation révisée du NIOSH. INRS, Paris, 6p.

[20] Chryssolouris, G., Mavrikios, D., Fragos, D. & Karabatsou, V. (2000). A virtual-based experimentation environment for the verification of human-related factors in assembly processes. Robotics and Computer Integrated Manufacturing, 16, 267-276.

[21] Jayaram, U., Jayaram, S., Shaikh, I., Kim, Y.J. & Palmer, C. (2006). Introducting quantitative analysis methods into virtual environments for real-time and continuous ergonomic evaluations. Computers in Industry, 57, 283-296.

Secretions of salivary melatonin and cortisol in Japanese healthy women, and their living environments

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ABSTRACT

Eight healthy female students (age 19 to 22 years, living in Fukuoka, Japan) participated in this study. The field study was conducted in two periods: September to October (Exp. 1) and January to February (Exp. 2). On a week in each experimental period, subjects were required to spend with a portable thermo-recorder and a wrist-type instrument which measure the intensity of light exposure, and to fill out the diary about bedtime and waking time, etc. Additionally, on a sixth day during each recording period, the subjects collected saliva samples by themselves at about three hours intervals. Secretory rhythms of melatonin and cortisol in subjects were examined by analyzing the saliva.

Bedtime and sleeping hours showed no significant difference between two experimental periods, while waking time was about 20 minutes earlier in Exp. 1 than that in Exp. 2 ($p<0.05$). Concerning environmental conditions, mean air temperatures around subjects were 25.3 °C for Exp. 1 and 16.0 °C for Exp. 2, with a significant difference ($p<0.01$). Subjects were exposed longer minutes to bright light during Exp. 1 compared to Exp. 2. Secretory profiles of melatonin showed similar rhythms in Exp. 1 and Exp. 2, i.e. reaching its peak level at night, while negative correlations were found in Exp. 1 between the exposure time to bright light (>=5000 lx, 12:00-15:00h) and the melatonin maximum level ($r=-0.74$, $p<0.05$) or total amount ($r=-0.75$, $p<0.05$). On the other hand, cortisol profiles, which peak in the early morning, showed a significant difference between the experimental periods ($p<0.01$), with higher levels in Exp. 1 compared to those in Exp. 2.

1. INTRODUCTION

Humans have a circadian rhythm of approximately 24 hours which the system is entrained by light-dark period, mainly by light exposure [1], and changed the light-dark exposure affects a timing of the circadian system [2]. For example, after individuals have been chronically exposed to long nights (scotoperiods), the duration of nocturnal periods of plasma melatonin secretions and rising plasma cortisol levels are longer than that after chronic exposure to short scotoperiods [3]. Early morning exposures to 800 lx light affected the morning rise in salivary cortisol, but evening exposures to light had no effect on cortisol secretion [4]. In addition to the effects of light on the circadian rhythm, it has been reported that bright light exposures at daytime affected the nocturnal plasma, serum and urinary melatonin secretion [5-8]. Hashimoto et al. [5] demonstrated that a significant phase-advance and significantly larger the area under the curve (AUC) of nocturnal melatonin rise in subjects who were exposed to bright light (5000 lx) during the daytime (11:00-17:00h) for 3 days, compared to them under dim light (200 lx) conditions. Park & Tokura [7] reported a significantly higher nocturnal melatonin amplitude in subjects who were exposed to bright light (5000 lx) during the daytime (06:30-19:30h) for 2 days compared to them under the dim light (200 lx) condition. Takasu et al. [8] also demonstrated that subjects who were exposed to dim light (10 lx) during waking period (16 h) for a week and were exposed to the bright light (5000 lx) for the same period in the next week, had significantly higher nocturnal melatonin peak levels in the second week than those in the first week. Furthermore, Mishima et al. [6] observed elderly residents with psychophysiological insomnia showed a significant increase of nocturnal melatonin levels and an improvement their sleep quality, by exposure to 4 h bright light (2500 lx) for 4 weeks. These reported studies are suggesting that a longer exposure to bright light during the daytime may be effective to enhance the nocturnal melatonin rise on each individual. However, in the modern life, it is expected that we tend to spend more time indoors where the thermal and lighting condition can be regulated, have less exposure to sunlight (bright light) during the daytime, and be exposed for longer time to the artificial lighting contrary to the natural photoperiod. In this study, therefore, the field study was conducted to examine the usual living environments (exposed thermal and light conditions) in young women as well as their circadian rhythms of salivary melatonin and cortisol, and possible effect of these environmental differences on melatonin and cortisol profiles in subjects living normally was investigated.

2. METHODS

2.1 Subjects

The subjects, who answered that they had the regular sleep-wake cycle and menstrual cycle in advance questionnaire, were selected from the participants. Eight healthy women (age 19 to 22 years) participated in this study. They were Japanese students in Fukuoka Women's University, living in Fukuoka, Japan (latitude 33°35´N). They were in good health, non-smokers, not taking any medication, and had no psychological problems.

The experimental procedures were fully explained to each subject, and written instructions were provided before subjects gave informed consent and the experiments began.

2.2 Procedures

The field study was conducted in two periods: from the latter part of September to October, 2007 (Exp. 1) and from January to the beginning of February, 2008 (Exp. 2). On a week in each experimental period, the subjects were required to spend with a portable thermo-recorder (Thermo-Recorder RS-11, Espec) and a wrist-type instrument (Actiwatch-L, Mini-Mitter Comp., Inc.) which measure the intensity of light exposure (lx) every 1 min, and they were also asked to fill out the diary about bedtime and waking time, etc. Additionally, from the sixth day morning to seventh day morning during each recording period, the subjects collected saliva samples by themselves at about three hours intervals (10:00, 12:00, 16:00, 19:00, 22:00, 01:00, 04:00, 07:00h), using collection tube Salivettes (Sarstedt, Rommelsdorf, Germany). The saliva sampling was carried out during follicular cycle on each subject. Secretory rhythms of melatonin and cortisol in subjects were examined by analyzing the saliva. The saliva samples were stored at −20°C until analysis using commercial ELISA kits for salivary melatonin (Buhlmann Laboratories AG Swiss) and cortisol (DRG Instruments GmbH, Germany).

2.3 Data Analysis

Concerning light exposure data measured by Actiwatch-L, the measurements were classified into five groups depending on light intensity (>=100, 500, 1000, 5000, 10000 lx) by counting the exposure minutes. The calculated values were also classified every three hours (0000-0300h to 2100-2400h, time of day). Furthermore, the calculations were carried out about the day of saliva sampling (i.e. single day) or all of measuring period (i.e. averaged 7 days).

2.4 Statistics

The means in each experimental period were compared by use of the paired *t*-test. Two-way ANOVA with repeated measures was adopted to compare times of day and experimental periods of air temperature, relative humidity, and melatonin and cortisol rhythms. The relation between the environmental factors (exposed thermal and light conditions) and endocrine hormonal parameters (melatonin or cortisol levels) was analyzed by Pearson's correlation coefficient test.

3. RESULTS

3.1 Exposure light condition on subjects

Figure 1 shows the daily aspects of light conditions that subjects were exposed during each experimental period. The means of the exposure light intensity differed significantly between times ($F_{23,161}$=12.22, p<0.01) and experimental periods ($F_{1,7}$=16.80, p<0.01), and there was a significant interaction ($F_{23,161}$=3.93, p<0.01). The total exposure minutes (min/day) to each intensity of light (>=500, 1000, 5000, 10000 lx) were all significantly longer in Exp. 1 than that in Exp. 2 (p<0.05).

3.2 Air temperature and relative humidity

Figure 2 shows air temperatures and relative humidity around subjects in the both experimental periods.

Mean ambient air temperatures (± SD) around subjects were 25.3 ± 1.5, 16.0 ± 2.2 °C for Exp. 1 and Exp. 2, with a significant difference (p<0.01, paired *t*-test). There were significant differences between times ($F_{23,161}$=25.48, p<0.01) and experimental periods ($F_{1,7}$=112.47, p<0.01), and there was a significant interaction ($F_{23.161}$=9.11, p<0.01).

Mean relative humidity (± SD) were 59.9 ± 2.8 and 46.9 ± 3.8 %RH for Exp. 1 and Exp. 2, with a significant difference (p<0.01, paired *t*-test). There were also significant differences between the times ($F_{23,161}$=23.70, p<0.01) and experimental periods ($F_{1,7}$=79.32, p<0.01), and a significant interaction ($F_{23,161}$=1.85, p<0.05).

3.3 Diary

The diary results are summarized in Table 1.Bedtime and sleeping hours showed no significant difference between two experimental periods, while waking time was about 20 minutes earlier in Exp.1 than that in Exp.2 (p<0.05).

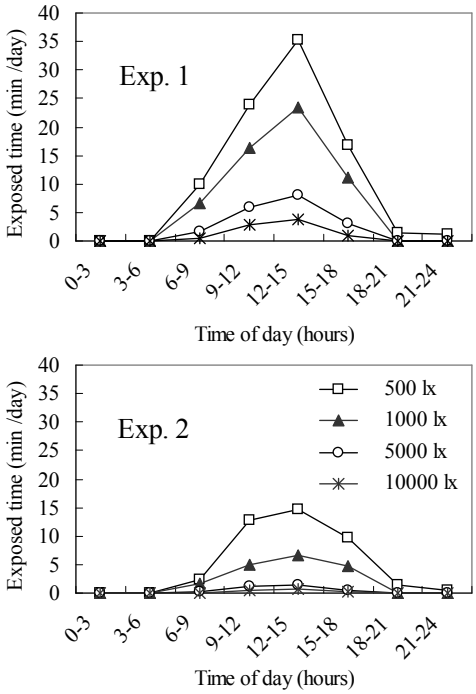


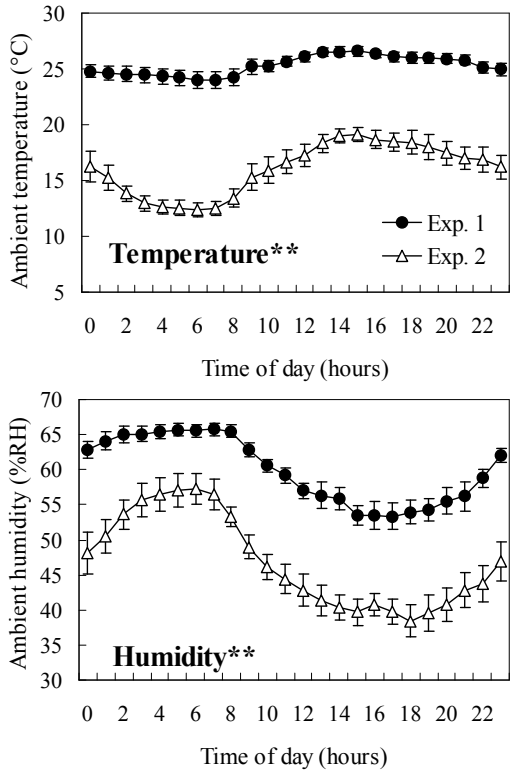
Figure 1: Averaged exposure time that subjects were exposed to each light intensity (*n*=8)

3.4 Melatonin and cortisol rhythms

The secretory profiles of melatonin showed similar rhythms in Exp. 1 and Exp. 2, i.e. reaching its peak level at night (Figure 3). There was significant difference between times ($F_{1.81,15.61}$=20.24, p<0.01), but no significant difference between experimental periods. Cortisol rhythms, which are peaking in the early morning, showed significant differences between times ($F_{1.99,13.94}$=17.40, p<0.01) and experimental periods ($F_{1,7}$=27.72, p<0.01), and the overall levels were higher in Exp.1 than those in Exp.2 (Figure 3).

3.5 Relationship between environmental factors and endocrine hormonal parameters

As for the relations between the environmental factors (mean air temperature and classified light data mentioned above in 2.3) and endocrine hormonal parameters (maximum levels and total amounts of melatonin or cortisol), there were significant negative correlations between the exposure time to bright light (>=5000 lx, 12:00-15:00h) and melatonin maximum level (r=–0.74, p<0.05; Figure 4) or total amount (r=–0.75, p<0.05), both in Exp. 1.



** p < 0.01, two-way repeated measures ANOVA, compared to experimental periods.

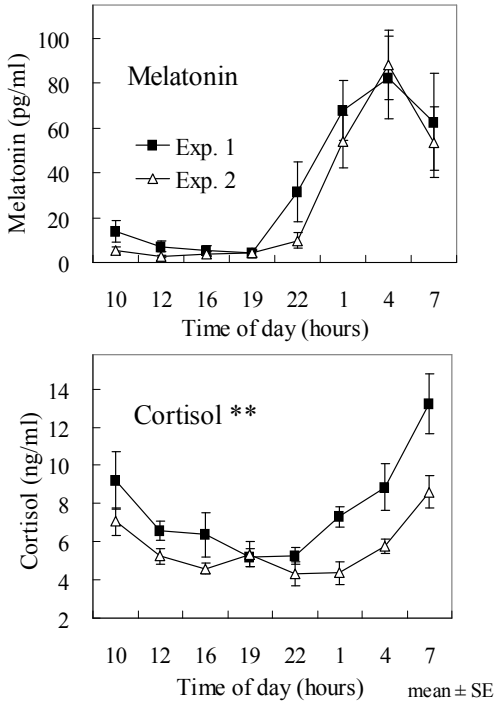
Figure 2: Air temperature and relative humidity around subjects (*n*=8)

Table 1: Questionnaire results for sleep parameters in each experimental period (*n*=8)

	Exp. 1	Exp. 2
Bedtime (time of day [h] ±min)	0:34 ± 43	0:52 ± 41
Waking time (time of day [h] ±min) *	7:43 ± 46	8:05 ± 55
Sleep duration (hours ± min)	7.01 ± 21	7.28 ± 50

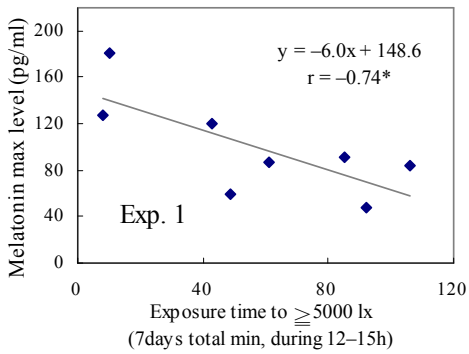
means ± SD

*p<0.05, paired *t*-test, compared to experimental periods.



** p < 0.01, two-way repeated measures ANOVA, compared to experimental periods.

Figure 3: Melatonin and cortisol rhythms (*n*=8)



* p < 0.05, Pearson's correlation coefficient.

Figure 4: Correlation between exposure time to bright light and melatonin maximum level (*n*=8)

4. DISCUSSION

In the comparison of two experimental periods, subjects were spending in thermally warmer and brighter light conditions in Exp. 1 compared to Exp. 2. The subjects were exposed longer to bright light during Exp. 1 than Exp. 2 (Figure 1). Especially in Exp. 1, the time of day which subjects were exposed to bright light was concentrated at 12:00-15:00h. The ambient temperature and humidity surrounding subjects were higher in Exp. 1 than that in Exp. 2 (Figure 2) as expected. However, the temperature in Exp. 1 was unusually hot, and recorded the highest mean temperature in the northern Kyushu area, Japan than usual (+2.9ºC in September, and +2.1ºC in October) since 1946, when the Japan Meteorological Agency started collecting data [9].

As for secretory profiles of melatonin and cortisol, there was a significant difference between two experimental periods in cortisol secretion rhythms, while no significances in melatonin secretions (Figure 3). Changed sleep schedule, under dim light condition for 6 days, was reported to shift the phases of salivary melatonin and cortisol rhythms [10]. It was also reported that early morning exposure to 800 lx light affected the morning rise in salivary cortisol, but evening exposure to light had no effect on cortisol secretion [11]. In this study, however, a significant difference in cortisol between two experimental periods appears to be derived from the differences of overall secretion levels rather than secretory changes at specific time or phase shifts, although waking time during Exp. 1 was about 20 minutes earlier (Table 1) and longer exposed to bright light in Exp.1 than that in Exp.2. Several researches have investigated seasonal variation in cortisol levels, and the results are conflicting. In a longitudinal study, Küller & Lindsten [12] investigated the morning urinary cortisol levels of school children in the months of September, December, February and May and they found lower cortisol levels in winter. Küller & Wetterberg [13] compared persons working in a subterranean environment (which was somewhat noisier and less bright) with those working above ground, measuring morning and evening urinary cortisol levels each month. They observed that only the morning cortisol levels displayed an annual pattern; in those working above ground, there was a gradual decline from September to January, followed by a sharp rise in February, these changes being less pronounced in the subterranean workers. Hansen et al. [14] studied diurnal and seasonal variations in endocrine functions in 11 women, and they found that concentrations of urinary cortisol were higher during December and January compared to the rest of the year. Our studies were carried out in Fukuoka in the south of Japan, and the climatic conditions differ from above reported studies executed in Northern Europe. Moreover, in a constant routine protocol, Van Dongen et al. [15] found no systematic seasonal variation in circadian phase of urinary cortisol in 6 men living in the Netherlands. These results may suggest that the regional climates act as an external factor

affecting cortisol secretion. A few studies have investigated the effects of extremely hot environments upon cortisol levels [16, 17]. Follenius et al. [16] found that plasma cortisol levels increased during heat exposure (48 °C or 55 °C) and rapidly decreased with falls in ambient temperature. Vangelova et al. [17] observed significantly higher urinary cortisol levels in heat-exposed workers (surrounding temperature was 32.7-47.3 °C) compared to a control group (29.0-32.7 °C) working in the same glass-manufacturing factory. The thermal condition in Exp. 1 was not as excessive hot as those reported studies, but it was unusually hot as mentioned above. If a rise of cortisol secretion could be caused by surrounding heat stress, seasonal changes of thermal conditions which occur in usual life (e.g. hot summer days) may also have chronically effects on cortisol secretion levels.

On the other hand, both the melatonin maximum level and total amount showed significant negative correlations with the daytime exposure time to bright light (>=5000 lx, 12:00-15:00h) in Exp. 1 (Figure 4), and cortisol data have no significances. These significant correlations of melatonin data in Exp. 1 were not observed with the light exposure data on saliva sampling day (single day), but with the data during measuring period (7 days). It is suggests that chronic (at least 7 days) daytime exposed to bright light conditions may affect the diurnal melatonin secretion. These negative correlations appear to inconsistent with reported studies [5-8] that are suggesting a longer exposure to bright light during the daytime may be effective to enhance the nocturnal melatonin rise. However, those reported studies [5-8] compared within subjects differ from our present study compared among subjects. Furthermore, in our previous study [18] investigated about seasonal variations of melatonin secretions in young women, 6 of 8 subjects had different melatonin secretory profiles in autumn (around equinox) with higher peak levels and phase delay of melatonin rise compared to other seasons. The melatonin peak levels of the 6 subjects also indicated a significant positive correlation with daytime exposure time to bright light (>1000 lx) in autumn, but the data from all 8 subjects had no correlation. In this study, to analyze in more detail, we classified exposed light data by light intensity and time of day, results in a finding the significant correlation. This correlation was observed in Exp. 1, which is the period that subjects were exposed longer time to bright light than those in Exp. 2, as well as the subjects in our previous experiment [18]. In addition, the saliva of subjects for hormone analysis was taken on the day without considering of menstrual cycle in our previous study. The results of reported investigations about effects of menstrual cycle on melatonin and cortisol in women are conflicting, but are partly indicated that the amplitude of the rhythms may be blunted in the luteal phase (reviewed in [19]). In this study, to unify the menstrual cycle, the saliva sampling was carried out during follicular cycle of each subject. Further longitudinal experiments will be expected to investigate the effects of surrounding factors (exposed thermal and light conditions) on the human circadian rhythms by compared within- and among subjects whether to generally expose to bright light during the daytime.

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6. REFERENCES

[1] Küller, R. (2002). The influence of light on circarhythms in humans. *Journal of Physiological Anthropology and Applied Human Science*, *21*, 87-91.

[2] Stevens, R.G., Blask, D.E., Brainard, G.C., Hansen, J., Lockley, S.W., Provencio, I., Rea, M.S., & Reinlib, L. (2007). Meeting report: the role of environmental lighting and circadian disruption in cancer and other diseases. *Environmental Health Perspectives*, *115*, 1357-1362.

[3] Wehr, T.A. (1998). Effect of seasonal changes in daylength on human neuroendocrine function. *Hormone Research*, *49*, 118-124.

[4] Scheer, F.A., & Buijs, R.M. (1999). Light affects morning salivary cortisol in humans. *The Journal of Clinical Endocrinology & Metabolism*, *84*, 3395-3398.

[5] Hashimoto, S., Kohsaka, M., Nakamura, K., Honma, H., Honma, S., & Honma, K. (1997). Midday exposure to bright light changes the circadian organization of plasma melatonin rhythm in humans. *Neuroscience Letters*, *221*, 89-92.

[6] Mishima, K., Okawa, M., Shimizu, T., & Hishikawa, Y. (2001). Diminished melatonin secretion in the elderly caused by insufficient environmental illumination. *The Journal of Clinical Endocrinology & Metabolism*, *86*, 129-134.

[7] Park, S.J., & Tokura, H. (1999). Bright light exposure during the daytime affects circadian rhythms of urinary melatonin and salivary immunoglobulin A. *Chronobiology International*, *16*, 359-371.

[8] Takasu, N.N., Hashimoto, S., Yamanaka, Y., Tanahashi, Y., Yamazaki, A., Honma, S., & Honma, K. (2006). Repeated exposure to daytime bright light increase nocturnal melatonin rise and maintain circadian phase in young subjects under fixed sleep schedule. *American journal of physiology. Regulatory, integrative and comparative physiology*, *291*, R1799-R1807.

[9] Fukuoka District Meteorological Observatory. (2007, 21-12-2007). Early report of meteorological observations in the northern Kyushu area, Japan in 2007 (Japanese). Retrieved 29-10-2008, 2008, from http://www.fukuoka-jma.go.jp/fukuoka/gyomu/osirase/2007tenkou.pdf

[10] Jelínková-Vondrasová, D., Hájek, I., & Illnerová, H. (1999). Adjustment of the human circadian system to changes of the sleep schedule under dim light at home. *Neuroscience Letters*, *265*, 111-114.

[11] Scheer, F.A., & Buijs, R.M. (1999). Light affects morning salivary cortisol in humans. *The Journal of Clinical Endocrinology & Metabolism*, *84*, 3395-3398.

[12] Küller, R. & Lindsten, C. (1992). Health and behavior of children in classrooms with and without windows. *Journal of Environmental Psychology*, *12*, 305-317.

[13] Küller, R. & Wetterberg, L. (1996). The subterranean work environment: impact on well-being and health. *Environment International*, *22*, 33-52.

[14] Hansen, A.M., Garde, A.H., Skovgaard, L.T., & Christensen, J.M. (2001). Seasonal and biological variation of urinary epinephrine, norepinephrine, and cortisol in healthy women. *Clinica Chimica Acta*, *309*, 25-35.

[15] Van, Dongen, H.P., Kerkhof, G.A., & Souverijn, J.H. (1998). Absence of seasonal variation in the phase of the endogenous circadian rhythm in humans. *Chronobiology International*, *15*, 623-632.

[16] Follenius, M., Brandenberger, G., Oyono, S., & Candas, V. (1982). Cortisol as a sensitive index of heat-intolerance. *Physiology & Behavior*, *29*, 509-513.

[17] Vangelova, K., Deyanov, Ch., Velkova, D., Ivanova, M., & Stanchev, V. (2002). The effect of heat exposure on cortisol and catecholamine excretion rates in workers in glass manufacturing unit. *Central European Journal of Public Health*, *10*, 149-152.

[18] Ueno-Towatari, T., Norimatsu, K., Blazejczk, K., Tokura, H., & Morita, T. (2007). Seasonal variations of melatonin secretion in young females under natural and artificial light conditions in Fukuoka, Japan. *Journal of Physiological Anthropology*, *26*, 209-215.

[19] Baker, F.C., & Driver, H.S. (2007). Circadian rhythms, sleep, and the menstrual cycle. *Sleep Medicine*, *8*, 613-622.

Bali Trail Ecotourism

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ABSTRACT

The Bali Trail is an ecotourism project focusing on education, environment and local awareness. Two Balinese villages have constructed walking tracks in and around their village to attract and educate tourists, and enhance the village with the profit.
By working with the local government and social organizations, the project was embedded in Balinese culture and village life. Indonesia, and especially Bali, is extremely hierarchic. The organization of the project had to be formed carefully, involving the right persons.
The feeling of equality was an important starting point. Inequality is fatal for a project, which is all about involvement, awareness and independence for the villages.
Step two was weaving the social structure and local government into the project. The project is for and by the whole village, so everyone should feel included. With an organization formed, the delicate process of making plans starts. Hierarchically, one leader initiates all involvement and is the source of new ideas. Experts on the field are invited to meetings and contribute for more detailed plans. If a westerner working on the project gives an opinion about the plans, this person easily slides into the role of 'boss', which damages the equality and the feeling of responsibility. Ideally, a westerner is sharing ideas with the leader. He will, if the ideas are good, adopt them as his own and present them to the rest of the team.
The design process has to be looked at differently than elsewhere. Some locations and designs are accompanied by ages of traditions and skill, sometimes incomprehensible for those not Hindu. Local solutions are almost always sufficient and better than foreign solutions. The only things that have to be stimulated are ergonomics and sustainability in design.

1. INTRODUCTION

Starting up a development project in rural Indonesia was a good opportunity to investigate cultural differences and how to integrate cooperation and education. Working together with professors, students, farmers and village chiefs offered a broad perspective on all the ways in which the Indonesian culture manifests itself.

By trying to bring knowledge of Ergonomics to Indonesia the realization came swiftly that the actual importance was to start understanding the tension fields between our cultures. Ergonomics, to begin with, are concerned with the context of the human being, making its environment comfortable, adjusted and understandable. How could anyone start with ergonomics and context, without thoroughly knowing the human being, its drivers and beliefs?

The Bali Trail ecotourism project was set up as a learning environment. Its goals were to bring knowledge of ergonomics to Indonesia by organizing, designing and communicating together. This article illustrates the learning curve of intercultural cooperation.

For further reading it is good to know the first author LT is the coordinating student that went to Bali together with two other students and preceded by another student; the second author JFM is the tutor that went to Bali at the beginning of this project and tutored the project remotely, by email and phone. This remote tutoring made the project very tough for the coordinating student.

The first Master student that went to Bali was Anne-Roos Hassing: she developed a locally produced wayfinding system. Annemarie de Vries (Msc student) went to Bali to work on a handbook about making and maintaining a trail. Sander Homs (Bsc student) went to Bali at the same time to work on the buiding of the physical elements of the Bali-trail in Petiga. Laura Talsma coordinated the whole progress of the two villages and helped create the organizations in the villages.

Remotely the following tutors were involved: Frans van Mourik as an expert in the history of Indonesia and an expert in visual design. Rob van Eersel, who has an own company Vivartis that developes ecotourism to Bali.

2. BALI TRAIL ECOTOURISM

Ecotourism incorporates all the beneficial factors of tourism, and turns all the negative factors around to make communities profit from it.

By educating villagers about their natural riches and how to sustain them and attract tourists with it, a closed loop can be made. Tourists come to small farmer villages, admire and learn from the local culture and nature, contribute to the local economy and thus create workplaces, and profit to

educate youngsters and sustain the local environment with.

The first village we started working with, Petiga, was far from the places most tourists come to on Bali. Most villagers lived from agriculture, but a lot of the younger people had to work in the tourist industry, making them part with their families for long periods at a time. The natural environment of the village is beautiful, but corrupted by large amounts of plastic and other waste. Many families do not have enough money to fund the education of their children, and the lucky few have to travel great distances for it.

Ergindo made a plan to create walking trails through the rice paddies and jungle, showing the local religion in the temples and the local agriculture in the fields surrounding the village.

Before such a plan could be made, the students got to know the culture and the village by staying at the hearth of a large family, acquainting with the chiefs of the village and learning the language.

The second village was found after making the plan for Petiga, and selected for its motivated inhabitants. One man had been uniting villagers to work together and help each other, his sight not troubled with economic gain, which is a often encountered problem, working in a third world country.

Because the aims matched, and a lot had been learned from Petiga, the cooperation was quicker than before.

2.1 Communication

The first item to deal with during design cooperation is the communication. Dutch people are not used to use or read the body language used in Indonesia, nor the strict hierarchy between people [1].

A lot of time has to be spent in forming an organization and settling into the roles. This cannot be rushed and will pay back precious time later on in the process. If several nationalities and cultures are merged (as they were in the teams on Bali) it has to be made clear what kind of role you will play in the team. Being put at the head of an organization is hard, especially when you do not know the individual qualities of its contributors. Acting like a group leader, when you are not the wisest in the field, will cause loss of valuable knowledge, and most importantly, a diminished feeling of responsibility within the team you are working with.

The role of a coach or advisor is better suited for foreign team members. In that way, the responsibility and status still lies with the group leader.

Strong cultural values are present in everyday life, and are manifested in working together. Superstition is an important value in the Balinese culture. Every event can be translated into messages and meanings. The powers of good and evil are fighting each other continuously and in strange forms. One of the students working in Bali had the misfortune to have the same characteristic hair the worst Hindu demons are depicted with. An opinion was formed that he was an evil force fighting with a good one. This does not mean that the person is directly disrespected, but under the skin a lot of emotions and associations take place.

Another tension field is jealousy and equality. Every person should be equal and those holding their heads higher will be mowed down or imitated. It is very important to see how everybody around you is living and how you are doing compared to them.

Figure 1: Working together

These issues came up during a solicitation day for ecotourism guides. One of the men from the leading team was asked to translate, in case misunderstandings took place. After a while it became clear that the translator told the applicant exactly what to say and do when they were at a loss for words. In his opinion, everybody was equally qualified to be a guide and he was optimizing the chances for all applicants. After the leading (Balinese) team selected the 'best' future guides, they did expect to enroll the others too.

These issues, when overlooked, can cause serious disruptions in teams. Misplaced egos, responsibility issues, short-term orientation and corruption are a few examples these issues can result in.

2.2 Organization

As As is said before, a feeling of responsibility is one of the most important emotions needed in a successful team. In Bali it had to be ensured that the project remains theirs all the time, not reigned by foreigners. The best way to start an organization in Bali is to have motivated people asking for help to come closer to their objectives.

One thing, which was very different from working in European teams, is that working together is so

very personal. Team meetings took place in the house of the team leader, who made you feel at home. Working as a coach for the organization, the life of LT was closely watched and evaluated. Some things are not easily understood in this very collectivistic society, such as living alone, and showing emotions openly. Learning to live with this and accepting it you will get accepted. Closing up and not wanting to learn deteriorates the relationship.

European values such as efficiency, speed and functionality are worthless in other working conditions. Balinese ceremonies take up lots of time and require working together closely.

They are not efficient, but extremely effective. Europeans do not readily accept this tension field. An optimal Balinese organization can be compared with a ceremony; effective, a joint effort bringing everybody together.

Figure 2: Ceremonies in Bali, bringing villages together

2.3 Design and development

Something, which had to be steered, was the design and development in both villages. Because most team members were Balinese farmers and craftsmen, their view on development was very different than those of Westerners, who will be guests and will also be the users of the products.

All the things designed for the walking trails had to be compatible with the Balinese (agri-) culture and had to be pleasant for foreign guests too. Two entirely different sets of criteria existed; one of comfort and ease (guests), and one of maintenance and agriculture (hosts).

The waste bins, for instance, were built in places, which were more comfortable to use for the official cleaners of the paths, employees of the Bali Trail. Signs had to be easy to read and recognizable for tourists, and cheap and easy to repair for the Balinese.

Ergonomics was something trivial in the perception of most of the team members, because people adjust themselves to their context, not the other way around. The woman in the picture (see Figure 3) helps with carrying bricks on her head to make stairs. The path is very slippery and dangerous and it is unhealthy to carry bricks on your head. Nonetheless, she adapts herself and is happy with the circumstances. If they had been better, fewer women would have earned a living carrying bricks!

Sustainability was also not always understood; if you can make plastic disappear by burning it, it is taken care of. The farmers did very well understand the weather has been changing over the years, which influences their harvests. By including the farmers in the Bali Trail organization, they learned how to take care of the environment. Making it very real for them and linking it to their personal health and income did plant a little seed in their minds.

Figure 3: Directional signs for tourists and Balinese ergonomics (Visual signs developed by Anne-Roos Hassing)

Imitating is a proven technique on Bali, when it comes to design. New things are based on past successes, and new demands and wishes are not really taken into account. It was hard combining the organizational structures with giving critical advise. All the designing has to be done together and the solution will be somewhere in the middle, a compromise between both cultures and knowledge fields.

Before the luxury of ergonomics and sustainability can be taught in a country like Indonesia, the necessity of it has to be made clear. An organization has to co-operate for a longer period, developing their village and making walking trails. After encountering problems they will gradually start to ask for ergonomic solutions and how to live in equilibrium with nature.

But, like in any third world country, it is surviving first and thinking of the rest later.

Figure 4: Resting place along the walking trail

3. CONCLUSION

Working on the Bali Trail has been a time of great challenges and great successes. Setting up an organization takes time and experience, but the organization will keep improving and adapting to the problems it encounters.

Ecotourism is a very special way of providing for your family, neighborhood, village and environment. It helped youngsters get an education, setting up a waste disposal system and maintaining the trails and nature around two villages.

The start of a beautiful co-operation has been made; trails have been created with a strong organization behind it. But teaching Balinese about Ergonomics and Sustainability takes a longer breath. The start has been made, but eventually the drivers and demands behind ergonomics and sustainability have to be experienced by the team members of the Bali Trail.

4. RECOMMENDATIONS

To make the Bali-trail effective the following tasks have to be fulfilled:

- Coaching the local villagers for the minimal expectations of the tourists like: the organization and maintenance of an open trail, toilets, meals and a downloadable guide. This organization could benefit the local economy a great deal.
- Coaching the villages in continuing and elaborating the educational systems and waste disposal system in the village.
- Creating and maintaining a website that shows the Western tourist how to come to the Bali Trail in Tampaksiring and Petiga and what to expect.
- Writing a grant proposal and organize (student) projects for these tasks.

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6. REFERENCES

[1] Hofstede, G., Hofstede, G.J. (2007). Allemaal andersdenkenden, omgaan met cultuurverschillen. Amsterdam, Uitgeverij contact.

[2] Lindberg, K. Hawkins, D.E. (1993). Ecotourism: a guide for planners and managers. North Bennington, Ecotourism Society

[3] Work by Adnyana Manuaba, Bali HESG, Udayana University of Denpasar, Bali

[4] www.ergonoom.nl

[5] cicat.tudelft.nl

[6] www.ncdo.nl

Research
in Physiological Anthropology and Design

Restorative Effects of Nature: Towards a Neurobiological Approach

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ABSTRACT

Many people have the feeling that contact with nature provides them with restoration from stress and mental fatigue. This common sense notion is increasingly supported by findings of well-controlled research. This paper gives a state-of-the art overview of research on the positive influence of nature on affective, cognitive, and physiological restoration. This overview shows that there is sufficient evidence for the restorative powers of nature. However, contrary to theoretical and intuitive notions, restorative effects of nature have shown little variation across settings, modes of interaction, or stress conditions. These unexpected findings may be partly due to measurement problems. To date, much of research on restorative environments has been limited self-reported mood measures, simple cognitive tests, and general, external physiological indicators of stress. These measures may not be sensitive enough to pick up changes in the complex psychological and physiological processes involved in stress regulation. Research groups in Japan and the Netherlands have recently begun to apply more specific, internal physiological measures, such as salivary cortisol, to the study of restorative environments. This neurobiological approach marks the beginning of a new era in restorative environments research. However, to fully exploit the possibilities of neurobiological studies, several steps must be taken. Most importantly, neurobiological restorative environments research should build upon the findings of previous research and theorizing. By doing so, the research can shed light on unresolved issues regarding theoretically and intuitively plausible variations in restorative effects across settings, interaction modes, and stressful circumstances. Furthermore, it is important to select measures that are specific to theoretically plausible neuroendocrine and autonomic stress mechanisms.

1. INTRODUCTION

Nature is highly valued by people. City councils spend large sums of money on saving urban woodland, developing parks, and planting trees along streets. Home-owners are willing to pay more for a dwelling if it has a garden or is situated in the vicinity of green space. And even the poorest members of society generally still find the money to buy a bunch of flowers or a pot plant to brighten their home.

One important reason why nature is so highly valued is that it offers excellent opportunities for relaxation and reflection. For many urbanites, the peace and quiet of a natural environment offers the perfect remedy to an increasingly stressful life. This is illustrated by a survey among 953 Swedish city dwellers.[1] Respondents were asked what they would recommend a close friend if he or she felt stressed or worried. The top 3 of recommendations was: (1) to visit a forest (mentioned by 86% of the respondents), (2) listening to restful music (mentioned by 83%) and (3) to take a good rest in a silent and quiet park (mentioned by 83%). Thus, city dwellers appear to have much faith in the effectiveness of nature-based stress-reduction strategies. In the same study, it was also found that individuals who more often visited urban open green spaces, less often reported stress-related illnesses.

The notion that contact with nature has relaxing and stress-reducing effects is increasingly substantiated by evidence from well-controlled research.[2] Thus far, this research has primarily relied on affective, cognitive and general physiological measures of stress (e.g., self-reported mood, concentration tasks, heart rate). More specific neurobiological measures (e.g. cortisol levels, cortical activity) have hardly been used. In 2004 the Health Council of the Netherlands[3] concluded that "There is strong evidence that nature has a positive effect on recovery from stress" (p. 54). However, one of the critical notes in this authoritative review was that the research should make better use of generally accepted neurobiological theories and measures of stress.

In the following paragraphs, I will first give a brief history of restorative environments research along with an overview of the main findings. Next, I will discuss some recent studies on restorative effects of contact with nature which have employed neurobiological measures. In closing, I will point out some promising avenues for future theorizing and research.

2. RESTORATIVE ENVIRONMENTS

2.1 Brief history

In 1979, Roger Ulrich conducted a pioneering study in which he measured the mood states of mildly stress students before and after they viewed slides of natural and urban settings. [4] The results indicated that the participants felt significantly better after viewing scenes of nature, rather viewing urban scenes lacking nature elements. In 1984, Ulrich published another landmark study in the prestigious journal Science.[5] In this study among gall-bladder patients he showed that patients recovering in rooms with a view of trees needed less strong pain medication, had shorter post-operative hospital stays, and received fewer negative evaluative comments in nurses' notes, than patients recovering in rooms overlooking a brick wall. Because the only difference between the two groups of patients was the view from their window, it can be assumed that stress-reduction was the central mechanism that caused the positive health outcomes.

In the same period in which Ulrich conducted his ground-breaking studies on stress-reducing and health improving effects of viewing nature, Rachel and Stephen Kaplan were studying the psychological benefits of nature experiences in different groups of people, such as gardeners [6] and participants of wilderness programs.[7] They discovered that individuals who engage in nature activities experience such deep comfort and relaxation that they feel therapeutic effects of nature. In 1989, the Kaplans formulated a theory, called Attention Restoration Theory (ART) to describe the therapeutic effects of nature.[8] They stated that restoration from mental fatigue is a central component of people's nature experience. They identified four components of people-environment interactions that contribute to attention restoration: being away (i.e., physical or psychological escape), extent (i.e., the sense of being in a whole other world); compatibility (i.e., environmental support of intended activities); and soft fascination (i.e., effortless attention).

Figure 1: Rachel & Stephen Kaplan

In the 1990s the ideas and findings of Ulrich and the Kaplans stimulated the development of a new research field which is now commonly referred to as "restorative environments research".

Terry Hartig, an American researcher working in Sweden, is one of the more prominent researchers in this field. Together with his colleagues, he has conducted many well-controlled experiments which show that visits to nature, or views of nature, can promote attentional, cognitive, and physiological recovery from mental fatigue.[9-12] Nowadays, restorative environments research is carried out in many countries, such as England [9], Italy [10; 11], Japan [12; 13], the Netherlands [14-17], South Korea [18; 19], and the United States.[20; 21]

Figure 2: Roger Ulrich (left) & Terry Hartig (right)

2.2 Main findings

Thus far, nearly all studies on restorative effects of nature have shown positive findings on at least one dependent measure.[16] In general, it has been found that contact with nature, as compared to non-natural settings, leads to a more rapid and more complete recovery from stress (measured in terms of self-reported mood, concentration tasks, or external physiological measures such as heart rate, blood pressure, skin conductance, or muscle tension). These effects have not only been found with urban settings as control conditions, but also with more rigorous control conditions, such as brightly colourful objects [22] or paintings [23]. In general, the findings have been remarkably consistent across settings, modes of interaction, and stress conditions.

2.2.1 Type of setting

When restorative environments research started out, many researchers expected that certain types of natural settings would be more restorative than others. Based on psycho-evolutionary theories, such as the stress recovery theory by Ulrich [24], it was hypothesized that natural settings that offered survival advantages during human evolution, such as settings with water, flowers, shelters or other cues for food and safety, would have superior restorative qualities. Research has not confirmed this hypothesis; restorative effects have been found for many different types of settings, ranging from single plants and plain grasslands to idyllic waterfalls and dense forests. Only few studies (less than 25%) have included subcategories of natural settings, which makes it difficult to draw conclusions on the contributions of physical

characteristics to restorative effects.[25] However, studies which have compared different types of natural settings have often failed to detect differences in restorative effects between the settings. For example, several studies [17; 26] have not found differences in restorative effects between settings with and without water, even though settings with water are generally thought to have soothing and calming qualities. Other studies [21; 27] have found some indications that certain types of natural settings and natural elements are more restorative than others, but the findings vary across measures of restoration, and are difficult to interpret. In general, restorative effects appear to be relatively unaffected by setting type, which is quite unexpected, given that aesthetic landscape preferences of people across the world are strongly and consistently influenced by the physical characteristics of the setting.[28]

2.2.2 Mode of interaction

Another unexpected finding is that restorative effects of nature are relatively independent of the mode of interaction. In particular, the available evidence suggests that brief, single-sensory exposure to simulated nature (e.g., viewing soundless videos, listening to sounds of nature) can be just as restorative as more prolonged and intensive contact with actual natural settings. For example, in one study among stressed participants it was found that readings of cardiovascular activity returned to normal after only 20 seconds of viewing movies showing puppies or waves on a small video monitor.[22] Japanese research has shown that even just the smell of cedar wood [29] or soft, murmuring sounds [30] can be sufficient to bring about changes in physiology indicative of relaxation. Again, only few studies have directly compared the effects of different modes of interaction with nature, with mixed results. In one study, screen size was manipulated to simulate conditions of low and high immersion.[14] The screen size manipulation did not have any influence on self-reported mood, in both conditions mood was fully restored after watching the nature movie. Effects of the screen size manipulation did, however, appear on physiological measures (skin conductance and heart rate variability). In another study [31] viewing a natural setting through a real window was found to be more restorative than viewing the same setting on the screen of a real-time plasma display. However, these findings should be interpreted with caution as they may also reflect the unusualness of looking at a live recording of a natural view on a video screen which sits in place of a glass window.

2.2.3 Stress conditions

There has been some debate regarding the mechanisms underlying restorative effects of nature. According to ART [8], restorative effects are mediated by a recovery from mental fatigue. This notion is consistent with the common experience that contact with nature is especially useful when one is mentally exhausted. By contrast, stress recovery theory [24] holds that restorative effects of nature reflect general stress or arousal reducing mechanisms. Several studies have tested these ideas by using specific fear-related stressors (i.e., watching a short scary movie) or attention-related stressors (i.e., carrying out demanding tasks for a long period of time). Results have indicated that contact with nature is an effective antidote against both affectively and cognitively induced stress.

The notion of "restorative effects" suggests that only individuals who are undergoing some sort of stress can benefit from contact with nature (because otherwise there is nothing to restore from). Consistent with this notion, some studies have found that the magnitude of restorative effects of nature increases with increasing stress levels.[12] However, contrary to the literal meaning of the term restorative, significant mood-improving and relaxing effects of nature have also been found in unstressed individuals.[32; 33] For example, Rachel Kaplan [33] has shown that having trees visible in the view from home substantially contributed to the "sense of being at peace" of unstressed, healthy residents. Based on these findings, Kaplan coined the term 'microrestorative experiences" to describe the kind of positive, "restorative" feelings that unstressed individuals derive from brief (indoor) interactions with nature.

2.2.4 Conclusion

Taken together, restorative environments research supports the widely held belief that contact with nature is a powerful means to relief stress. However, the findings seem to contradict conventional wisdom that some nature experiences, such as standing outdoors contemplating an actual waterfall, are more restorative than other experiences, such as sitting indoors viewing slides of plain grasslands. In general, restorative effects have shown little variation across settings, modes of interaction, or stress conditions. This robustness of effects may reflect a genuine aspect of the restorative powers of nature. Indeed, it has been argued that restorative effects of nature are grounded in primitive brain systems that automatically react to simple cues of "naturalness" regardless of the circumstances or needs of the observer.[34]

Alternatively, it is also possible that the inconclusive evidence regarding the influence of type of setting, mode of interaction, and stress conditions on restorative effects of nature is (partly) due to measurement problems. To date, much of research on restorative environments has been limited to fairly general, external physiological indicators of stress (heart rate, blood pressure, GSR), self-reported mood measures, and simple cognitive tests. These measures may not be sensitive enough to pick up changes in the complex psychological and physiological processes involved in stress regulation.

Back in 1991, Parsons already stressed the need for "more specific physiological measures, such as stress hormones and indicators of immunocompetence" in restorative environments research.[35] His advice has only been only recently given attention, especially by research groups in Japan studying the neurobiological correlates of "shinrin-yoku" (forest air-bathing and walking).

3. NEUROBIOLOGICAL STUDIES

3.1 Shinrin-yoku and gardening

"Shinrin-yoku" is a popular form of relaxation therapy in Japan. It involves walking and breathing in the atmosphere of the forest. For about a decade, Japanese researchers have been trying to substantiate the health benefits of shinrin-yoku by means of rigorous experimental studies employing advanced neurobiological measures. Much of this research has been published in Japanese only; however, a growing number of studies are being published in the English language, making the research accessible to an international audience.

An early study was published back in 1998 in the International Journal of Journal of Biometerology.[36] This study showed that blood glucose levels of diabetic patients significantly decreased after walking 3 km or 6 km in the forest. The researchers theorized that the substantial decreases in glucose levels suggested an additional effect of the forest environment besides the effects of being physically effective; however the uncontrolled design of their study did not allow any firm conclusions about the added value of walking in a forest environment.

A more recent series of studies indicates that a three-day trip to forest fields can strengthen the immune system of healthy adults.[37-39] In two uncontrolled studies, it was found that the forest trip increased natural killer (NK) cell activity, the number of NK cells in the blood and the expression of anti-cancer proteins in males [39] as well as females [37]. In the study among female subjects, follow-up measures were conducted which showed that these effects lasted at least 7 days after the trip. The superior immune-strengthening qualities of forest environments over other environments are demonstrated in a more controlled experiment, in which healthy male adults went on three-day trips to a forest and a city.[38] The forest bathing trip significantly increased NK cell activity and the numbers of NK and protein expressing cells and significantly decreased the concentration of adrenaline in urine. By contrast, a city tourist visit did have any positive influences on the immune system.

Figure 3. Experimental conditions used in the study by Park et al. (2008)

Another series of controlled studies among healthy young men investigated the effects of shorter stays of 15-20 minutes in forest and city environments.[40-42] All studies found that concentrations in salivary cortisol were lower after watching the forest than after watching the city environment (although these effects seem to be largely due to the stress-increasing effects of being in a city, and initial differences in salivary cortisol). In addition, one study [41] found that cerebral activity on the left side of the forehead (measured by absolute hemoglobin concentrations in the blood) was significantly lower after walking in the forest than after walking in the city. Another study [42] found significant positive influences of shinrin-yoku on psychological and general physiological measures (blood pressure, pulse rate, heart rate variability), but failed to demonstrate positive effects on Immunoglobulin A, an antibody that fights bacterial and viral infections in the upper respiratory and gastrointestinal tracts.

The positive influences of nature-based activities on salivary cortisol found in the Japanese studies are corroborated by findings from our own research group in the Netherlands. We recently conducted two controlled experiments in which we studied the restorative effects of gardening and a stay in a green conservatory in a home for the elderly. [43] In both experiments, participants were first subjected to stress-inducing treatments before they were assigned to the environmental conditions. The results show significantly stronger decreases in salivary cortisol in the natural conditions than in the non-natural control conditions.

3.2 Future directions

The neurobiological studies discussed in the previous paragraph mark the beginning of a new era in restorative environments research, in which more specific and sensitive physiological measures are being applied to study restorative effects of nature. However, in order to fully exploit the possibilities of these new measures, certain steps must be taken. Below, I will outline a few suggestions for making better use of neurobiological measures in future research on restorative environments.

First, neurobiological studies of restorative effects of nature should build upon the findings of previous research and theorizing. One important lesson to learn from previous work is that it is important to include different subcategories of natural and non-natural settings, different modes of interaction, and/or different stress conditions. By doing so, the research can shed light on unresolved issues regarding theoretically and intuitively plausible variations in restorative effects.

Furthermore, it is important for neurobiological restorative environments research to select measures that are specific to theoretically plausible neuroendocrine and autonomic stress mechanisms. For example, Attention Restoration Theory has placed much emphasis on the reduction of mental fatigue as a central mechanism underlying restorative effects of nature. Recent research in the area of work-related stress has indicated that mental fatigue is related to impairment of high-level regulatory control processes and a decrease in the supply of dopamine in certain brain areas involved with pleasure and mood. [44] Thus, in order to demonstrate a crucial role of mental fatigue in restorative effects of nature, it seems useful to employ measures that tap into high-level regulatory processes and dopaminergic circuits in the brain.

Finally, I would like to point out that the paper written by Parsons in 1991 contains many interesting hypotheses that have thus far remained untested. [35] Most importantly, Parsons has suggested that an encounter with nature engages two affective responses. He describes these responses as follows: "The first is immediate, subcortical, based on simple stimulus information that is presented to hard-wired environmental feature detectors and mediated by the amygdala. The second is more deliberate, involves neocortical processing and the comparison of incoming information with stored information (possibly including the communication of the comparison outcome to the amygdala for evaluation), and is hippocampally mediated. It has also been suggested that these two limbic affective response systems have counterparts in the FOF and GAS neuro-endocrine responses, the former being fast and associated with the amygdala, while the latter is somewhat slower and associated with the hippocampus." (p. 17) This "dual restoration theory" can explain much of the contradictions found in restorative environments research, in particular the finding that mood-lifting effects of nature appear to be more universal and insensitive to specific environmental and situational conditions than cognitive and physiological effects. It is up to future research to substantiate these claims.

4. REFERENCES

[1] Grahn, P., & Stigsdotter, U. A. (2003). Landscape planning and stress. *Urban Forestry & Urban Greening, 2*(1), 001-018.

[2] Van den Berg, A. E., Hartig, T., & Staats, H. (2007). Preference for nature in urbanized societies: Stress, restoration, and the pursuit of sustainability. *Journal of Social Issues, 63*(1), 79-96.

[3] Health Council of The Netherlands (2004). *Nature and Health. The influence of nature on social, psychological and physical well-being* (No. 2004/09). The Hague: Health Council of the Netherlands and Dutch Advisory Council for Research on Spatial Planning.

[4] Ulrich, R. S. (1979). Visual landscapes and psychological well-being. *Landscape Research, 4*(1), 17-23.

[5] Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 224*(4647), 420-421.

[6] Kaplan, R. (1973). Some psychological benefits of gardening. *Environment and Behavior, 5*(2), 145-162.

[7] Kaplan, R., & Talbot, J. F. (1983). Psychological benefits of a wilderness experience. In I. Altman & J. F. Wohlwill (Eds.), *Human behavior and environment: Advances in theory and research* (Vol. 6, pp. 163-203). New York: Plenum Press.

[8] Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. New York: Cambridge University Press. .

[9] Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research, 15*(5), 319-337.

[10] Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25*(3), 249-259.

[11] Berto, R., Massaccesi, S., & Pasini, M. (2008). Do eye movements measured across high and low fascination photographs differ? Addressing Kaplan's fascination hypothesis. *Journal of Environmental Psychology, 28*(2), 185-191.

[12] Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., et al. (2007). Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health, 121*(1), 54-63.

[13] Oishi, Y., Kanehama, S., Hiyane, A., & Taguchi, H. (2003). Comparison of forest image and mood: psychological examination in a forest environment using profile of mood states and semantic differential method. *Journal of the Japanese Forestry Society, 85*(1), 70-77.

[14] De Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & Ijsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology, 26*(4), 309-320.

[15] Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning, 86*(2), 115-125.

[16] Van den Berg, A. E. (2005). *Health impacts of healing environments: A review of the benefits of nature, daylight, fresh air and quiet in healthcare settings*. Groningen: Foundation 200 years University Hospital Groningen.

[17] Van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology, 23*(2), 135-146.

[18] Park, S. H., & Mattson, R. H. (2008). Effects of flowering and foliage plants in hospital rooms on patients recovering from abdominal surgery. *Horttechnology, 18*(4), 563-568.

[19] Shin, W. S. (2007). The influence of forest view through a window on job satisfaction and job stress. *Scandinavian Journal of Forest Research, 22*(3), 248-253.

[20] Kuo, F. E., & Sullivan, W. C. (2001). Aggression and violence in the inner city - Effects of environment via mental fatigue. *Environment and Behavior, 33*(4), 543-571.

[21] Parsons, R., Tassinary, L. G., Ulrich, R. S., Hebl, M. R., & Grossman-Alexander, M. (1998). The view from the road: Implications for stress recovery and immunization. *Journal of Environmental Psychology, 18*(2), 113-140.

[22] Fredrickson, B. L., & Levenson, R. W. (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cognition & Emotion, 12*(2), 191-220.

[23] Lohr, V. I., & Pearson-Mims, C. H. (2000). Physical discomfort may be reduced in the presence of interior plants. *HortTechnology, 10*(1), 53-58.

[24] Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Human behavior and environment: Advances in theory and research* (Vol. 6, pp. 85-125). New York: Plenum press.

[25] Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes - Landscape types in environmental psychology. *Urban Forestry & Urban Greening, 6*(4), 199-212.

[26] Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201-230.

[27] Lohr, V. I., & Pearson-Mims, C. H. (2006). Responses to scenes with spreading, rounded, and conical tree forms. *Environment and Behavior, 38*(5), 667-688.

[28] Ulrich, R. S. (1993). Biophilia, biophobia and natural landscapes. In S. R. Kellert (Ed.), *The biophilia hypothesis* (pp. 73-137). Washington, DC: Island Press.

[29] Miyazaki, Y., Morikawa, T., & Yamamoto, N. (1999). Effect of wooden odoriferous substances on humans. *Applied Human Science: Journal of Physiological Anthropology, 18*(5), 189.

[30] Mishima, R., Kudo, T., Tsunetsugu, Y., Miyazaki, Y., Yamamura, C., & Yamada, Y. (2004). Effects of sounds generated by a dental turbine and a stream on regional cerebral blood flow and cardiovascular responses. *Odontology, 92*(1), 54-60.

[31] Kahn, P. H., Friedman, B., Gill, B., Hagman, J., Severson, R. L., Freier, N. G., et al. (2008). A plasma display window? The shifting baseline problem in a technologically mediated natural world. *Journal of Environmental Psychology, 28*(2), 192-199.

[32] Hartig, T., Book, A., Garvill, J., Olsson, T., & Garling, T. (1996). Environmental influences on psychological restoration. *Scandinavian Journal of Psychology, 37*(4), 378-393.

[33] Kaplan, R. (2001). The nature of the view from home - Psychological benefits. *Environment and Behavior, 33*(4), 507-542.

[34] Joye, Y. (2007). Architectural lessons from environmental psychology: The case of biophilic architecture. *Review of General Psychology, 11*(4), 305-328.

[35] Parsons, R. (1991). The potential influences of environmental perception on human health. *Journal of Environmental Psychology, 11*(1), 1-23.

[36] Ohtsuka, Y., Yabunaka, N., & Takayama, S. (1998). Shinrin-yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients. *International Journal of Biometeorology, 41*(3), 125-127.

[37] Li, Q., Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., et al. (2008). A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. *Journal of Biological Regulators and Homeostatic Agents, 22*(1), 45-55.

[38] Li, Q., Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., et al. (2008). Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. *International Journal of Immunopathology and Pharmacology, 21*(1), 117-127.

[39] Li, Q., Morimoto, K., Nakadai, A., Inagaki, H., Katsumata, M., Shimizu, T., et al. (2007). Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. *International Journal of Immunopathology and Pharmacology, 20*(2 Suppl 2), 3-8.

[40] Park, B. J., Tsunetsugu, Y., Ishii, H., Furuhashi, S., Hirano, H., Kagawa, T., et al. (2008). Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. *Scandinavian Journal of Forest Research, 23*(3), 278-283.

[41] Park, B.-J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., et al. (2007). Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) - Using salivary cortisol and cerebral activity as indicators. *Journal of Physiological Anthropology, 26*(2), 123-128.

[42] Tsunetsugu, Y., Park, B.-J., Ishii, H., Hirano, H., Kagawa, T., & Miyazaki, Y. (2007). Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in an old-growth broadleaf forest in Yamagata prefecture, Japan. *Journal of Physiological Anthropology, 26*(2), 135-142.

[43] Custers, M. H. G., & Van den Berg, A. E. (2007). *Nature, stress, and cortisol: experimental research into the influence of gardening and activities in green conservatories on physiological, affective, and cognitive restoration from stress* (No. 1629). Wageningen: Alterra {In Dutch only}.

[44] Lorist, M. M., Boksem, M. A. S., & Ridderinkhof, K. R. (2005). Impaired cognitive control and reduced cingulate activity during mental fatigue. *Cognitive Brain Research, 24*(2), 199-205.

Office interior design effects on meetings

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ABSTRACT

The effects of differences in office interior design are studied on meetings. To stimulate organizational creativity (or social innovation) the coffee corners were changed in an enterprise. The experiment showed that a coffee corner with screens separating the corner from the work floor and a possibility to sit resulted in more conversations than a coffee corner which is open and had no seats. To stimulate activation in formal meetings a height adjustable sit-stand meeting table with VDU screens was introduced. Sharing information with a projector on a screen reduced movement compared with screens on the table. So, informal and formal meetings can be influenced by the interior design.

1. INTRODUCTION

Some manufacturers in the Netherlands have the vision that additional new offices will be more a meeting place and not an office with many cells where employees will do their job separated from each other. Additionally, all kinds of other innovations are introduced as well. New chairs, new tables, new meeting furniture, new storage systems, new computer systems, other means by which you can work (e.g. PDAs) are becoming constantly available. In addition, there are new tasks and new interiors. Traditional offices and office settings continue to exist with daily on-sight interactions while less traditional settings for example, remote offices, or home offices are becoming more commonplace and accepted. The diversity in office interiors is therefore growing. However, the research basis for the ideal office interior is still weak [4] and more research is needed in this area. Something to consider when investing in a new office is to access whether the office has the desired effect that the business or occupants intend to reflect to the outside world and whether the interior provides an environment for optimal performance and health and wellness for employees. However, it is difficult to study these effects and there is a limited amount structured knowledge available.

2. TWO STUDIES

This paper is part of a program which is an attempt to contribute to the lack of effect studies regarding office interiors. Two studies are presented in this paper, which were chosen based on the idea that the office will be more a meeting place and that creativity will be more important. According to Brauer [2] work will become more knowledge intensive. Simple work will be done by technology, but the creative work will be done by the employees. In a knowledge based and innovation driven competitive business environment, a company that needs to compete on innovation needs its organizational members for developing novel and useful ideas for solving problems and developing new products, services, processes, systems, and work methods. This creative potential of the workforce needs to be stimulated and work environments need to be designed to support worker creativity [5]. To facilitate this creativity two types of meetings will be studies: informal meetings and formal meetings. The effects studied will consider experienced effects of employees and recorded effects.

3. STUDY 1: COFFEE CORNER EFFECTS

Effects of the office interior on creativity have been described before in the literature (see table 1). Hypotheses and effects have for instance been described on the effects of plants and space for informal meetings on creativity.

Table 1: Some relationships between office environment characteristics and creativity described in the literature

Some office interior characteristics stimulating creativity	Source
Plants inspire employees	Shibata & Suzuki, 2004 [9]
80% of the creative ideas come from informal meetings	Lloyd, 2001 [8]
Spaces for informal meetings stimulate creativity	Haner, 2005 [6]
Create breaks with toys to stimulate creativity	Snead & Wykoff, 1999 [10]

Assuming that some relationships described in the literature are true, we tested a hypothesis based on these relationships. If 80% of the creative ideas come from informal meetings and if coffee lounges are needed to stimulate informal meetings it would be good to have a coffee lounge facility that is often used and where often informal conversations are found. We also assume that the type and location of the coffee corner influences these effects. Therefore, our hypothesis is:

The type and location of coffee corners have effects on the number of meetings between employees and on the informal conversations.

3.1 Method

To test the hypothesis a pilot study was done in an office [12], where the coffee corner was located and designed in two different ways. In the first situation the coffee corner was located in the office garden. Everyone could see who was drinking coffee, because there was no protection. There was no possibility to sit. In the new situation the coffee corner was located more central in the office environment and screens were positioned that could increase the privacy feeling. Also, seats were added and a table with magazines enabling conversations and rest breaks. A new system of measuring was developed. It consisted of cameras and microphones recording movements and sound (see fig. 1). The cameras and microphones were positioned in such a way that

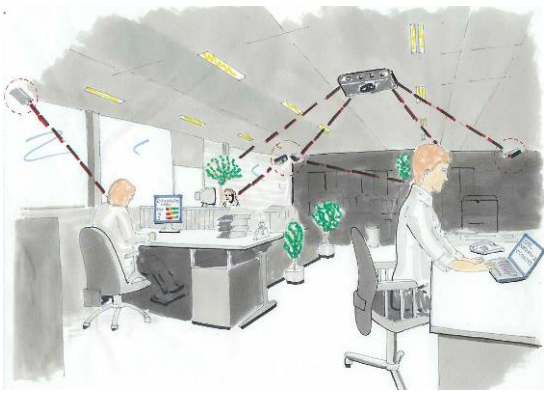

Figure 1: The recording system showing an office environment and cameras and microphones recording a whole day work.

every part of the office environment could be recorded visually and sound synchronously. Software was developed to analyze the data afterwards. To establish whether two or more persons were around the coffee corner, a line was drawn in the camera recordings around the coffee corner. The software recorded when two or more people were within the line. At that moment the sound was switched on (by the programmed software) and recorded whether or not subjects were discussing. These talks were analyzed. Topics of one subject were clustered. Like a short conversation on the weather was seen as one "talk" and typified as private. When this conversation was followed by a discussion on how to answer a certain phone call of a client this work this was defined as another "talk" typified as work. All "talks" were recorded in the old and new situation during a day work at an office where about 50 employees work. The t-test was used to measure significant differences ($p<0,05$). Additionally, in interviews with 7 employees the meaning of the new coffee corner was asked.

3.2 Results

The position and design of the coffee corner had no significant effect on the number of movements to and from the coffee corner. There was a significant difference in number of "talks" (see table 2). The new situation resulted in more talks and the length of the talks was approximately the same leading to more conversation time. The percentage of conversations on work and on non-work issues did not differ significantly. About 84-90% of the conversations concern work issues and about two third is about strategic issues. The interviews showed that the employees liked the new coffee corner as they now also have the possibility to talk with colleagues planned and unplanned. The impression was that is was nice to have more possibilities share operational and strategic issues with colleagues in a more closed environment. They experienced more social support. Coffee corner location and design have influence on the number of talks. Even in a situation where less people meet each other around the coffee corner more "talks" were recorded. In one visit more "talks" were recorded as the subject changed frequently. Probably the feeling of having more privacy and the possibility to have a seat did stimulate the participants to have more "talks". Interesting is the fact that between 84 and 90% of the conversations is about work. Especially, as Lloyd [8] describes that 80% of the creative ideas come from informal meetings and Creelman [3] states that coffee lounges are needed to stimulate informal meetings. In this study it is clear that a coffee corner with seats and tables and screens that increase the privacy feeling stimulate the number of conversations. Most of the work conversations increase and it seems that more strategic questions are discussed in the situation with more privacy. However, the number of non-work conversations increases as well.

Table 2: Differences in movements and conversation characteristics between two different types of coffee corners, *=significant effect

Type of effect	**old**	**new**
Number of movements to coffee corner	239	170
Number of "talks" recorded by the system*	338	514
Percentage of "talks" about work	90%	84%
Percentage of "talks" about strategic aspects of work	51%	63%
Percentage of "talks" about operational work aspects	39%	21%
Percentage of non-work "talks"	10%	16%

3.3 Discussion

It was interesting to see that there was a difference in conversation related to the design of the interior. The number of talks was higher around the coffee corner probably due to the fact that the interior gave them more privacy and there was a possibility to sit inviting the subjects to take more time. Generalization of these pilot test results to other office situations is difficult. Other enterprises could have another work content and the results can be different for other types of work and another population. However, the indication found in this paper that coffee corners that invite to discuss and have privacy lead to more informal conversations on work is not illogical. There could be a relationship with health and productivity of the position of the coffee corner. One of the important aspects of productivity in the future is creativity (see introduction), 80% of the ideas come from informal meetings and coffee corners could support that. Regarding health it might be interesting that social support did increase in the new situation in the perception of employees. Svard et al. [11] described that social support reduces stress. Therefore, the coffee corner could even contribute to health improvement.

4. STUDY 2: EFFECTS OF A SIT-STAND MEETING TABLE

The second study concerns an official meeting. One of the issues in the Netherlands is that work is too often static. In this paper we assume that more variation in movement improves the comfort and well-being. To stimulate more movement we tested the effect of a height adjustable meeting table in combination with seats in which it is possible to have a meeting while sitting, standing and "leaning". The hypothesis for this research is: people move more in a meeting room enabling a leaning (half standing) position than one in a sitting position (Hypothesis 1). The assumption is also that looking at one public screen that is placed outside the group on a wall reduces movement as members are mostly focused on the screen and not on the other participants of the meeting. The hypothesis is therefore: Participants in a meeting with a public screen outside the group move less than in a meeting with a screen placed in the middle of the group (Hypothesis 2). The idea is also that this more movement leads to more activation and a better productivity or creativity (Hypothesis 3).

4.1 Method

To check the hypotheses a special height adjustable meeting table for 6-8 persons was made (see fig. 2). Additionally eight height adjustable seats were used, which have the possibility of a normal seating position and a half-standing position (see fig. 3). The meeting table was equipped with two flat screens in the middle of the table to allow participants to watch the public screen simultaneously while looking at other participants. 111 subjects (mostly Industrial design students from Delft University of Technology) in groups of 2-7 participated in the experiment having 21 meetings in which the participants discussed the progress in their project. 8 groups worked at a "normal" meeting table height (table height 75 cm). 11 groups in the "half standing position". 2 groups were in the sitting position and used additionally a projector. The meeting is part of a course they do for which they get graded. The content varies from informing co-student or teacher, present results to each other or decisive meetings. The hypotheses is that in the half sitting position participants would move more frequently and in case of the projector less movement should be the result fixing the participants even more.

Questionnaires were used directly after the meetings to ask whether the subjects had the feeling that they were moving and whether they liked the configuration. Also, measurements were done with four video cameras mounted in the corners of the room. The number of changing pixels was counted automatically as an indication for movement. Averages and standard deviations were calculated and a double sided t-test was performed ($p<.05$).

Fig. 2: The height adjustable meeting table in use during a meeting performed in a standing posture.

Fig. 3: The height adjustable chair. In the left picture the middle of the seat is lifted here to prevent gliding off the seat.

4.2 Results

In table 3 an overview is shown of the recorded change in pixels. All three situations were significantly different from each other ($p < .05$). Most changes in pixels and therefore movements of persons during the meeting are found in the half standing position. In table 4 an overview is shown of the experienced changes in postures according to the participants of the meeting. This was not significantly different except for the projector situation. Looking at a screen with one projector shows that the participants do not move much. This is in alignment with the recorded pixel change. In table 5 the average meeting activation caused by the meeting room configuration is shown according to the users. In fact no significant differences are shown here.

Fig. 4: the meeting table in the half standing position with the screens on the table

Table 3: Changes in pixels on the video recording in the three different meeting rooms. A higher score means more changes.

Setup	mean	SD	nr of meetings
Normal meeting room configuration	1.23	0.29	8
Meeting room half sitting	1.63	0.47	11
Meeting room with projector	0.85	0.04	2

Table 4: Number of mentioned changes in postures by the subjects.

Setup	mean	nr of meetings
Normal meeting room configuration	0.20	8
Meeting room half sitting	0.18	11
Meeting room with projector	0.09	2

Table 5: Mean experienced activation on a scale from 1-7 (7 max activation)

Setup	mean	nr of meetings
Normal meeting room configuration	4.46	8
Meeting room half sitting	4.48	11
Meeting room with projector	4.32	2

4.3 Discussion

Hypothesis 1: the number of changed pixels is indeed a little bit higher, but the experienced movement is not in alignment with these results. This means that it is difficult to find out - based on these data- whether more movement is found during half sitting. Hypothesis 2: The pixels as well as the experienced movement clearly indicate that the number of movements is less in the situation with a public screen placed outside the group compared with both half sitting and sitting with a screen on the table, which means that our hypothesis is affirmed. Hypothesis 3: There are no indications that the subjects feel more activated, which could lead to better results. The fact that we didn't find clear effects is not in alignment with other studies. Konijn et al., [7] found more movement in a normal computer task while using tables and seats that make sitting, half sitting and standing possible. Bluedorn et al. [1] did find more movement during standing in meetings. According to Bluedorn et al. [1] sit-down meetings were 34% longer that standing meetings, but they produced no better decisions. In our case the time of the meeting was fixed, which means that we could not find effects on duration of the meeting. Perhaps in the half standing position the meeting would have been shorter if we have subjects decide on the moment of ending the meeting, which makes subjects more aware of efficiency. The reason for the difference could be the length of the recording. Konijn [7] recorded the whole day, while in this paper 1.5 hour of work was recorded. Also, the meeting time in the study of Bluedorn et al. [1] was longer. Another reason for the difference could be that the experienced difference in movement was not reflecting the real difference in movement.

4.4 CONCLUSIONS

Informal meetings can be influenced by the office interior design. The coffee corner experiment showed that a coffee corner with screens separating the corner from the work floor and a possibility to sit resulted in more conversations than a coffee corner which is open and had no seats. In both coffee corners more than 4 out of 5 conversations were about work. These informal discussions could contribute to more creativity. It could also contribute to a better health as social support could reduce stress. Also, formal meetings can be influenced by the interior design. Sharing information with a projector on a screen at one side of the room reduced human movements compared with screens on the table.

5. REFERENCES

[1] Bluedorn, A.C., Turban, D.B., Love, M.S., 2003. The Effects of Stand-Up and Sit-Down Meeting Formats on Meeting Outcomes. Journal of Applied Psychology Volume 84, Issue 2, April 1999, Pages 277-285

[2] Brauer, W., Lozano-Ehlers, I., Greisle, A., Hube, G., Keiter J. & Rieck, A., 2003. Office 21 – Push for the future better performance in innovative working environments, Cologne/Stuttgart: Fraunhofer

[3] Creelman D. The Secrets of Office Design (2006) http://www.managementsite.com/content/html/276.asp?cid=688

[4] Croon, E.M. de, Sluiter J.K., Kuijer, P.P.F.M., Frings-Dresen, M.H.W., 2005. The effects of office concepts on worker health and performance: a systematic review of the literature. Ergonomics 48(2):119-134.3.

[5] Dul J, Ceylan C. Enhancing organizational creativity from an ergonomics perspective: The creativity development model. In: Pikaar RN, Koningsveld EAP, Settels PJM, Eds. Meeting Diversity in Ergonomics. Proceedings IEA2006 Congress. Oxford: Elsevier (2006) CD-rom: art0111.

[6] Haner U. Spaces for creativity and innovation in two established organizations. Creativity and innovation management 3(2005) 14.

[7] Konijn I, Jongejan B, Berg M, Vink P. Comfort and movement during standing, half standing and sitting VDU work (in Dutch: Comfort en bewegen bij staand en half zittend beeldschermwerk). Tijdschrift voor Ergonomie 2008;33(2):14-19.

[8] Lloyd, P. Creative Space. Newport KY Peter Lloyd Inc. (2001), http://www.gocreate.com/articles/cspace.htm.Blumenthal, H. (2006). In Search of Perfection. London: Bloomsbury Publishing PLC.

[9] Shibata S, Suzuki N. Effects of an indoor plant on creativity task performance and mood. Scandinavian Journal of Psychology, 2004; 5:373–381

[10] Snead L, Wycoff J. Stimulating innovation with collaboration rooms. J. for Quality and Participation, http://www.thinksmart.com/articles/collaboration_rooms.html, (1999).

[11] Svärd E, Aringer L, Baneryd K, Frostberg C, Kemmlert K. Systematic Work Environment Management and Stress. Solna: The Swedish Work Environment Authority, 2002.

[12] Vink P, Korte E de, Blok M, Groenesteijn L. Effects of the Environment on Productivity and Health: Coffee Corner Position. HCI International 2007, Bejing. Berlin: Springer, 2007. DVD:157-162

Evaluation of Environment: Background and Examples

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ABSTRACT

This paper deals with the evaluation of environment in man-environment system. The man-environment usually classifies into two large groups, natural and artificial environment. The natural environment consists of physical, chemical and biological factors. The typical examples of physical environmental factor are temperature, humidity, atmospheric pressure and so on. The well-known chemical factors are O_2, CO_2, CO, O_3 and so on. The biological factors consist of plants, virus, bacteria and so on. The artificial environmental factors are the above three, physical, chemical and biological, and social factor. The social factor is often called political factor. The main components of the social factor are industry, education, medical service, welfare and so on. It was shown that the man-environment system had interactive, complicated and nest structures. Understanding these structures leads to evaluation properly environment factors. It was also pointed out that there were two groups of environmental factor, sensory and non-sensory factor. Evaluation of non-sensory environmental factor relates safety and security of the subject. On the other hand evaluation of sensory environmental factors leads active environmental design and control. In addition the classification of indoor and outdoor environment was introduced and the predominance of indoor environmental factors was discussed together with several examples. Finally several examples of evaluation of environment were introduced including standards for public building in Japan, evaluation tool of man-thermal environment and indoor radon.

1. INTRODUCTION

Nowadays evaluation of environment is one of important research fields. However the content of environment varies depending on its host or subject. For example, zebra-environment system is strikingly different from lion-environment system. The present topics deal with evaluation of environment in man-environment system.

2. FACTORS OF MAN-ENVIRONMENT

The man-environment usually classifies into two large groups, natural and artificial environment. Artificial environment is frequently called man-made or built environment. The natural environment consists of physical, chemical and biological factors. The typical examples of physical environmental factor are temperature, humidity, atmospheric pressure, light, sound and vibration. The well-known chemical factors are O_2, CO_2, CO, O_3, SO_x, VOCs and waste matters. The biological factors consist of plants, virus, bacteria, parasites, insects and animals. The artificial environmental factors are the above three, physical, chemical and biological, and social factor. The social factor is often called political factor. The main components of the social factor are industry, education, medical service, welfare, administration, economy, transportation, information and religion (see Figure 1).

3. SENSORY AND NON-SENSORY FACTOR

It was shown that the man-environment system had interactive, complicated and nest structures. Understanding these structures leads to evaluate properly environment factors. It was also pointed out that there were two groups of environmental factors; sensory and non-sensory factors. Table 1 shows main sensory system in the human body. Human sensory system consists of three groups, special, somatic and viscera sensation. The first group, vision, audition, palate, olfactory and equilibrium sensation are closely related to evaluation of environment. Second group is also related to evaluation of environment. The representatives of sensory environmental factor are temperature, light, sound, vibration and odorants. Those of non-sensory environmental factor are CO, odorless substances, radioactivity etc. Evaluation of non-sensory environmental factor relates safety and security of the subject. On the other hand evaluation of sensory environmental factors leads active environmental design and control.

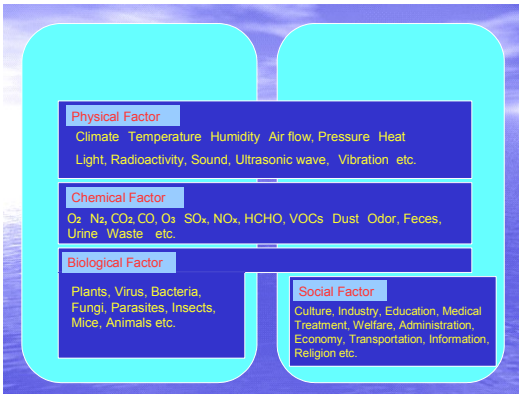

Figure 1: Structure of man-environment system

4. INDOOR AND OUTDOOR ENVIRONMENT

The next important classification in man-environment system is indoor and outdoor environment. The term of indoor environment, as used here, encompasses all enclosed spaces occupied by human, including home, work, shopping, education, entertainment, and transportation places.

Recently, the most of the population spend the bulk of its time indoors. Actually since 1970s male adults in Tokyo megalopolis Japan spent 22 hours and more per day and female adults spent 23 hours and more per day. Therefore it was thought that indoor environmental factors might be more important than outdoor. There are many reasons why the types and concentrations of indoor environmental pollutions are growing. For example, the energy crisis beginning in the early 1970s led architects, engineers, building managers, and home owners to take steps to conserve energy, including reduction in the infiltration of outside air, and greater use of synthetic building and decorative materials. While these actions generally achieved their purpose of reducing energy costs, they often resulted in increasing indoor concentrations of chemical and biological substances. In addition, the synthetic materials and decorations increasingly being used in homes and buildings can release new chemicals into the indoor environment.

Table 1: Main sensory system in the human body Main sensory system in the human body

	Modality of sensation	Receptor Location
Special Sensation (Cranial nerve transimission)	Vision	Retina
	Audition	Cochlea
	Palate	Tongue & Oral cavity
	Olfactory	Olfactory epithelium
	Equilibrium	Three semicircular canals
Somatic Sensation (Somayic nerve transmission)	Tactile	Skin & mucosa
	Pressure	
	Vibration	
	Thermic	
	Cold	
	Pain	
	Itch	
	Tickling	
	Smooth	
	Bathyesthesia	Muscle, Tendon, Joint & periostem
Visceral Sensation (Splanchnic nerve transmission)	Hunger	Stomach
	Thirst	Pharynx
	Vomiturition	Abdominal cavity
	Uresiesthesis	Bladder
	Defecation	Rectum
	Visceralgia	Each internal organ

5. RAPID INCREASING INDOOR LIFE TIME

One of important human activities would be industry activity. The well known industry activities are generally divided into three groups, primary, secondary and tertiary industry[2]. In 19th century the places of almost industry activities are outdoors especially primary industry including agriculture and fishery. However, the recent working places of the secondary or manufacturing industry, for example, semiconductor manufacturing industry is at triple indoors. The common working places of the tertiary or commerce industry are indoors. This tendency seems to extend to the primary industry including agriculture and fishery. Concerning agriculture vinyl plastic hothouse, glasshouses and plant factories are increasing. In fishery industry indoor growing ponds, tanks and pens are gradually used.

Let's consider sport activities. The picture shown in Figure 2 was picked up from the famous musical drama named "west side story" produced in 1957. The main scene of this musical drama was the front of outdoor basket ball court. At that same time Japanese students played the basket ball in outdoor courts. In 1950s both USA and Japan almost basket ball courts were outdoors. In the 1960s, Japanese student played the basket ball in the gymnasium or indoor court. After then volleyball players rushed into indoors. Tennis players also used to play at indoor court. Now baseball players do indoor stadium.

Figure 2: Typical example of outdoor basket ball court

The place of war activities also shift from outdoor to indoor. Figure 3 shows the outline of Napoleon Bonaparte (1769~1821) 's the Russian Campaign in 1812. At that time both commander and soldiers operated outdoors. In the modern war commanders are active in operator room. The president negotiates with hot line in the White House. The general decides to switching missile in the Pentagon. All these are indoors.

Figure 3: Typical example of war activities in 1812

6. SEVERAL EXAMPLES OF EVALUTION OF ENVIRONMENT

6.1 Indoor Environmental Standards for Public Building in Japan

First example of evaluation of environment concerns Indoor Environmental Standards for Public Building in Japan since 1970.

The items are 1) Air Temperature (Ta), 2) Relative Humidity (RH), 3) Air Movement (Va), 4) Carbon Dioxide (CO2), 5) Carbon Monoxide (CO), 6) Suspended Particulate (SP) and 7) Formaldehyde (HCHO).

These Indoor Environmental Standards are adopted for the following buildings; 1) Theatre; Department Store; Assembly Hall; Library; Museum; Gallery; Recreation Hall (Floor area more than 3000m^2), 2) Store; Office (Floor area more than 3000m^2), 3) Private or Special School (Floor area more than 8000m^2) and 4) Hotel (Floor area more than 3000m^2).

However these standards only set static state of environmental factors. In addition almost these standards are not complete from point of view of Physiological Anthropology. 1) air temperature], 2) relative humidity and 3) air movement are called as thermal environmental factors. However these standards lack the other essential thermal environmental factors.

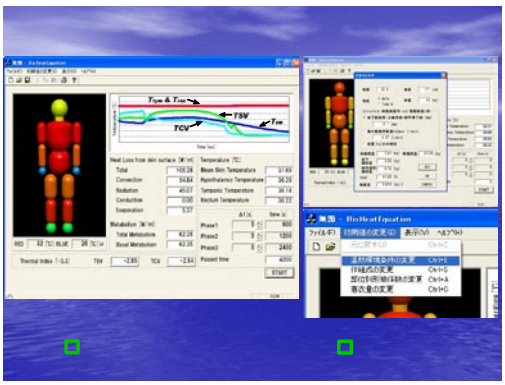

Figure 3: Outlines of new evaluation tool of thermal environment system

6.2 New Evaluation Tool of Man-Thermal Environment System

We developed an evaluation tool in order to make a precise evaluation of human thermal physiological and psychological responses[4]-[6],[8]-[14],[16]-[17]. Figure 3 shows the outline of the present evaluation system. Assigning input data for example physical characteristics of each subject, thermal environmental factors, clothing resistance of each segment and activity levels and so on, we can obtain whole body temperatures and heat fluxes and thermal sensation vote TSV and thermal comfort vote TCV of each time step. Figure 4 shows the flowchart for the present computer program. First step is the subroutine of assigning physical characteristics of the subject and thermal properties. After meshing subroutine we should set the initial conditions of thermal environmental factors, activity level and body temperatures of each segment. For transient state calculation, changing state subroutine for thermal environmental factors and activity levels is included. Next step is the calculation procedure of thermoregulatory response outputs. This part is consisted of perspiration rate, skin blood flow rate, and shivering heat production rate of each segment. The regulated output was triggered by information on deep temperature, the preoptic

area and the anterior hypothalamus temperature and mean skin temperature. Because research on sweating regulation was progressing, the model was also modified by the local skin temperature itself and the rate of change in mean skin temperature. Characteristics of each segment were represented by the relative coefficient of perspiration, relative ratio of blood flow and relative ratio of shivering thermogenesis proposed by the author. The following step is the calculation of heat exchange between each segment and thermal environment. In case of water immersion, convection heat transfer is dominant. Final step is the calculation of arterial and venous blood temperatures of each layer and segment and the calculation of whole body tissue temperatures and heat fluxes.

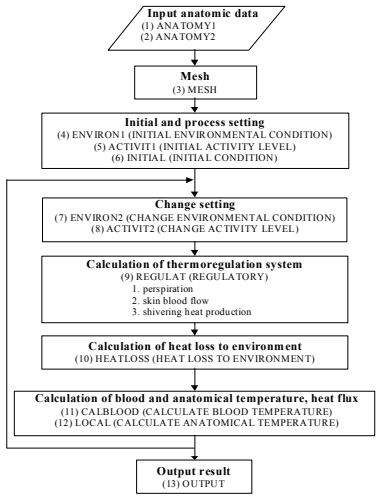

Figure 4: Flowchart of new evaluation tool of thermal environment system

There are four procedures of assignment of body dimensions and composition. The easiest way is the use of the average subject's data set. For the precise prediction of temperatures and heat fluxes within human body anatomical data corresponding to individual differences are essential. The second way is the assignment of data modified from the average subject's anatomical data set with simple somatometric measurements, for example, body weight, height and skin fold thickness. The third one is the procedure using individual shape data by three dimensional body surface scanning technology, which affords precise length, volume and surface area of each segment. The fourth and most detailed one is the assignment of individual anatomical data obtained by computerized tomography.

Table 2: Indoor Environmental Standards for Public Building in Japan

1) Air Temperature (Ta): 17-28 [°C],

2) Relative Humidity (RH): 40-70 [%],

3) Air Movement (Va): 0.5[m/sec],

4) Carbon Dioxide (CO2): 1000[ppm],

5) Carbon Monoxide (CO): 10[ppm],

6) Suspended Particulate (SP): 0.15[mg/m3]

7) Formaldehyde (HCHO): 0.1[mg/m3]

6.3 Evaluation of Indoor Radon

We introduced our several efforts for improving our evaluation of man-environment system[1],[3],[7],[15],[18]. Next topic is concerning the representative of non-sensory environmental factor and serious environmental pollutant. Radon is a naturally occurring radioactive gas that is colorless, odorless, and tasteless. It is a part of the naturally occurring radioactive decay chain from radiogenic uranium to stable lead. Radon 222, which has a half-life of 3.8 days, is the product of radioactive decay of radium 226. Radon decays with emission of an alpha particle to polonium 218, which has a half-life of approximately 3 minutes. Figure 5 shows the mechanism of lung cancer induced with Rn-daughters. First important event is the deposition of polonium 218 in the lungs. At the next stage alpha radiation (particle) might break one or both DNA strands at the cell level.

How radon may enter homes. 1) Radon in ground water enters well and goes to house; 2) Radon gas in rocks and soil migrates into basement through cracks in foundation and pores in construction; 3) Radon gas is emitted from construction materials used in building the house.

Table 3 shows the measured results of radon concentration by the author. The basement concentration is high and outdoor concentration is quite low. Brick and RC house concentrations are higher than wooden house.

Table 3: Measured results of Radon concentration[15]

House Type	Sample Size	Mean(Bq/m^3)	Max(Bq/m^3)
Concrete Detouched	38	44	242
Concrete Apartment	40	33	127
Wooden House	40	22	48
R-2000 Type House	29	7	19
Basement	2	139	231
Outdoor	28	2	4

It was pointed out that the ancient people were short-lived. One of the reasons why they had relatively high risk of lung-cancer. They lived in

grottoes and/or semi-basement or pit houses, had high risk of Rn problem compared with wooden houses and the raised floor construction houses. It is known that marble contains less radioactive substances. The ancient kings empirically might noticed that marble would be safety, Rn free construction materials. They earnestly gathered marbles and constructed palaces with them.

Next the topic of evaluation of environmental Rn might be introduced. Table 4 summarizes several standard values of indoor Rn. However it is pointed out that local deposition rate of Rn-daughters is depending on size distribution. Therefore we performed direct measurement of the particle size distribution of radioactive aerosol. Figure 6 shows the typical measured results of particle size distribution of radioactive aerosol obtained at public underground space. By using data of particle size distribution of radioactive aerosol deposition rates of particle in respiratory organs were calculated. The calculated results showed that the deposition rate in alveolus and alveolar duct might be extremely high.

Table 4: Standard values of indoor Radon

Standard Name	[Bq/m^3]	Remarks
WHO	100	New construction
ASHRAE	100	
EPA	148	(=4pCi/l)
Sweden	70	New construction
Sweden	200	Renovation
Sweden	400	Old construction

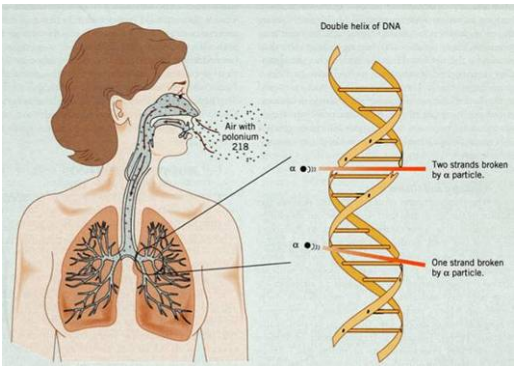

Figure 5: Mechanism of lung cancer induced with Rn- Daughters [1]

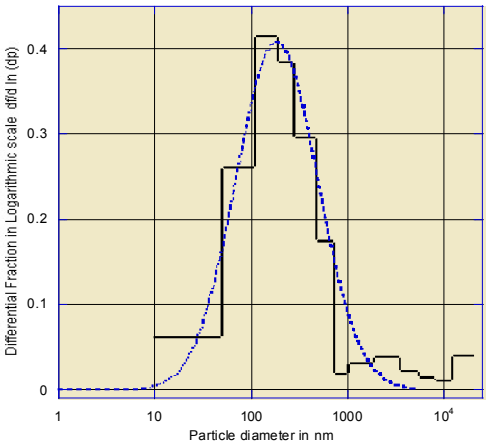

Figure 6: Measured indoor particle size distribution of Rn-Daughters [18] of lung cancer induced with Rn daughters

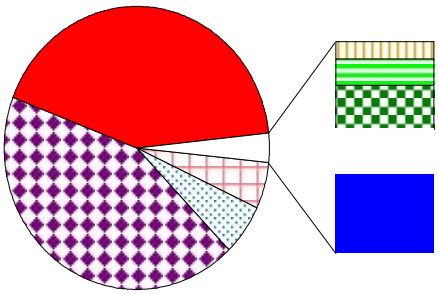

Figure 7: Calculated deposition rate of Rn-Daughters to respiratory organ[3] ,[18] indoor particle size distribution of Rn-Daughters of lung cancer induced with Rn-daughters

7. REFERENCES

[1] Botkin, D. B. & E.A. Keller (1995). Environmental Science. John Wiley & Sons.

[2] Clark, C.(1951). The Conditions of Economic Progress. 2nd ed. London Macmillan.

[3] Ito, T., Aoki T., Yokoyama S., Shimakura K., Fujiyoshi R. & Zhuo W. (2005). Investigation of Behavior Pattern and Risk Assessment of Natural Radioactive Substances in Urban Facilities. Proceedings of 3rd International Conference of Human-Environment System, 396-399

[4] Kakuta, N., Yokoyama, S., Nakamura M., & K. Mabuchi (2001). Estimation of Radiative Heat Transfer Using a Geometric Human Model. IEEE Transactions on Biomedical Engineering, Vol. 48(3), 324-331

[5] Kakuta, N., Yokoyama S., & Mabuchi K. (2002). Human Thermal Models for Evaluating: Comparing Infrared Images Under Various Thermal Environmental Conditions Through Normalization of Skin Surface Temperature. IEEE Engineering in Medicine and Biology, Vol. 21, 65-72

[6] Mizuta Y., Kakuta N., & Yokoyama S. (2001).A General System for Three-Dimensional Analyses on the Basis of CFSV-Model and its Application to the Airflow Analysis around a Human Body. Computational Fluid Dynamics Journal, Vol. 9, 528-540.

[7] Rahman n. m., Iida T., Yamazawa H., Yokoyama S., Moriizumi J., Saito F. & Ito T. (2007). The study of activity median aerodynamic diameter using imaging plate technique for assessment of effective dose from radon and its decay products. Radiation Protection Dosimetry, Vol.124, 360-371.

[8] Yokoyama, S. & Ogino, H. (1983). Theoretical and Experimental Studies on Calculation Formula of Respiratory Heat Loss. Jap. J. Biometeor., Vol.20, 1-7.

[9] Yokoyama, S. (1993). Heat Transfer Phenomena in the Human Body. Hokkaido University Press, Sapporo. (in Japanese)

[10] Yokoyama, S., Kakuta, N. & Ochifuji, K.(1997). Development of a New Algorithm for Heat Transfer Equation in the Human Body and its Applications, Appl. Human Sci., 16, 153-159.

[11] Yokoyama, S., Kakuta, N., Togashi, T., Hamada, Y., Nakamura, M. & Ochifuji, K. (2000a). Development of Prediction Computer Program of Whole Body Temperature Expressing Local Characteristics of Each Segment : Part 1 Bio-Heat Equations and Solving Method, Trans. SHASE, 77, 1-12.

[12] Yokoyama, S., Kakuta, N., Togashi, T., Hamada, Y., Nakamura, M & Ochifuji, K.(2000b). Development of Prediction Computer Program of Whole Body Temperature Expressing Local Characteristics of Each Segment: Part 2 Analysis of the Mathematical Model for the Control of Skin Blood Flow. Trans. SHASE, 78, 1-8.

[13] Yokoyama, S., Kakuta, N., Togashi, T., Nakamura MI, Masaki, T., Hamada, Y., Nakamura,MA & Ochifuji, K.(2002). Development of Prediction Computer Program of Whole Body Temperature Expressing Local Characteristics of Each Segment: Part 3 Comparison of Measured and Calculated Results. Trans. SHASE, 84, 43-52.

[14] S. Yokoyama, N. Kakuta, Y. Mizuta & K. Mabuchi (2002). Simulations of Airflow and Substance Concentration around a Human Body. J. Physiol. Anthrop. and Applied Human Science, Vol. 22, 215-222.

[15] S. Yokoyama, T. Tsukidate, T. Aoki, E. Saigan, H. Utsumi, K. Ikeda & T.Iida (2003). Measurement of Indoor Radon and Its Daughtaers in Hokkaido. Journal of Society of indoor Environment, Japan, 9-17.(in Japanese)

[16] Yokoyama, S., M. Tao & N. Kakuta (2007a). Prediction Computer Program for Whole Body Temperatures and its Application under Various Working Level and Thermal Environmental Condition Combinations. Industrial Health, 45, 118-124.

[17] Yokoyama, S., Maeda, T., Kuramae, M. & Kakuta, N. (2007b). Human thermal model expressing local characteristics of each segment: J. Human-Environment System, 10, 51-61.

[18] Yokoyama S., Ito T., Masuda H., T. Iida, K. Shimakura & S. Kobayashi (2007c). Investigation of Behavior Pattern and Risk-Assessment of Main Indoor Air Pollutants in Sapporo and Nagoya City. Part 2: Natural Radioactive Substance. IAQVEC2007, Proceeding 2, 293-298.

Measuring Chinese Heads and Faces

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ABSTRACT
The Size China 3D anthropometric survey used a combination of traditional anthropometric methods and current laser scanning technologies to create a high resolution 3D digital database of the Chinese head shape. The survey followed international standards for the collection of statistically accurate 3D data on Chinese head shape. Scanning was done at seven different sites across mainland China, collecting data for use in the design of "Chinese fit" products for the head and face.

1. INTRODUCTION
Many different kinds of headgear today satisfy important human practical and symbolic needs in areas ranging from health care to fashion. To ensure that headgear fits properly, designers must rely on anthropometric data to provide information on the size and geometry of the human head.
However, traditional anthropometric head data has suffered from two limitations. First, the complex geometry of the head and face is not well described by traditional univariate measurements, which capture head length, width and circumference only as numerical values. Secondly, univariate anthropometric surveys have traditionally examined only Western populations, with few surveys collecting data on Chinese populations.
The limitations implicit to numerical univariate data have been recently overcome with the application of digital 3D scanning to anthropometric research. Using 3D scanning, researchers can obtain true 3D spatial co-ordinates for the complex geometry of human body shape.
The problems caused by ethnically skewed data have also been addressed by recent 3D scanning projects completed on groups in Korea and Japan. However, these scanning studies were addressed at defining the size and shape of the body overall, for applications in the clothing and intimate apparel industries. As a result, they did not capture a very high resolution on small and geometrically complex parts of the body like feet, hands, heads and ears, because the realistic upper limit of an individual computer file is limited to about 20MB. A whole-body 3D scan at a file size of 20MB gives only a low-resolution description of the head and face. At the same time, the head is very demanding in terms of fit because many head products must be physically rigid to serve their function. Unlike clothing, rigid helmets cannot flex or stretch to suit variations in body shape. What are the best methods to capture high resolution 3D data for Chinese head and faces?
SizeChina aimed to overcome the limitations of previous surveys by applying digital scanning methods to the Chinese head alone to achieve high-resolution results.[1] As a late-generation anthropometric study, SizeChina was able to benefit from "best practices" developed in previous studies. Existing international anthropometric standards provided clear guidance on the type of data required, as well as the procedure required to calculating the number of subjects needed to achieve significant results.[2][3]

2. PLANNING THE SURVEY
2.1 Sampling Locations
Popular opinion in China has long suggested that a size difference exists between larger people to the north, and smaller people to the south. In undertaking the first-ever 3D anthropometric survey of head shape in China, the opportunity existed to collect data that could substantiate or refute that common idea. To capture variations, sites were chosen that were widely spread across different regions of the mainland, and which also met the project criteria of regional diversity. The six sites selected coincided with the sampling locations of a traditional anthropometric survey that was conducted in mainland China in 1988.[4] Hong Kong was the site for the initial training and refining of the measurements methods

The seven sites were:
- Hong Kong — the home site for training and establishment of protocols;
- Guangzhou — in the south of China;
- Huangzhou — in coastal/central China;
- Chanquin — south/east central China;
- Lanzhou — north/east central China;
- Beijing — north/east China;
- Shenyang — far northern China.

Figure 1: Scanning Locations in China

2.2 Subject Demographics

Traditionally, much traditional anthropometric data was originally collected by the military to meet needs in the development of uniforms and equipment. Military studies have always suffered from restricted demographics, because they primarily survey young males of military fitness. Subjects who are older or younger than military age are excluded, as are the physically disabled, while women are under-represented.

The goal of the SizeChina survey was to be as inclusive as possible in the recruitment of subjects. Three age groups were established: 18-30, 30-50, and 50-70+; with men and women surveyed separately, for a total of six categories. No restrictions were placed on the height, weight or social status of subjects. All individuals were of the Han ethnic group. All subjects were paid volunteers and the survey followed ethical research guidelines.

2.3 Number of Subjects Needed

In collecting anthropometric data, the number of subjects needed for a study is normally calculated based on the variability of the dimensions being surveyed, and on the level of accuracy and precision required for the final data. Guidance on making the calculations is provided in The ISO (International Organization for Standardization) standard 15535:2006, "General requirements for establishing anthropometric databases," the description of which is as follows:

ISO 15535:2006 specifies general requirements for anthropometric databases and their associated reports that contain measurements be taken in accordance with ISO 7250 ["Basic body measurements for technological design"]. It provides necessary information, such as characteristics of the user population, sampling methods, measurement items and statistics, to make international comparison possible among various population segments.[5]

For SizeChina, the size of the sample needed was calculated independently for each of the six locations so that each would stand alone as a significant survey in itself. The extent of anthropometric variability within China was relatively unknown. Treating each of the sites separately permitted their results to be compared to one another.

To calculate the necessary size of the survey, ISO 15535:2006 stipulates the use of the coefficient of variation of a key dimension obtained from a previous survey. Since no previous surveys of Chinese head and face size were available, we took a figure from a U.S. Army head survey to serve as a comparison benchmark.[6] The variation co-efficient is not itself a dimension, but only a measure of how much a particular dimension varies across the population. While American head measurements are clearly different from Chinese head measurements, there was no reason to assume that either group has a broader range of variation. It can be safely assumed that both groups vary by the same relative amount.

The minimum sample size of the group needed at each survey site, *n*, was calculated using the following formula:

$$\mathrm{CV} = \frac{\mathrm{SD}}{x} \times 100$$

where:
1.96 is the critical value (z value) from a standard normal distribution for a 95% confidence interval; and CV is the coefficient of variation with mean *x*; and SD is the standard deviation of the population for the body dimension in question; and *a* is the percentage of relative accuracy desired.

The Menton-Sellion Length describing the length of the face was selected for use as the key dimension for our calculation, because it provides a key dimension commonly used by designers in sizing devices made for facial protection as well as a good overall measure of face size. Using its coefficient of variation, calculations showed that a sample size of 254 at each site would yield results with 1% accuracy at the 5th and 95th percentiles.

When the 254 subjects to be surveyed at each site were divided into the three age categories and two sexes, a total of 43 people were needed in each category. This was rounded up to require 45

people in each group, for ease of communication with the local sites. The total number of subjects required at each site therefore increased to 270 subjects, up from the required 245, increasing the redundancy of the survey at each location.

Table 1: Sampling Matrix for Each Location

AT EACH LOCATION			
Age	**Male**	**Female**	
18 - 30	45	45	
31 - 50	45	45	
51 - 70	45	45	
Gender Total	**135**	**135**	
Location Total			**270**

Based on this matrix, the total number of individuals surveyed across all six sites was 1,620. With each of the six sites alone calculated to be statistically significant in terms of the survey data, the study overall became highly redundant, making its results extremely reliable. The 400 children surveyed were in addition to the 1,620 adults.

Table 2: Sampling Matrix for the Entire Survey

LOCATION	**Site Total**
Lanzhou	270
Shanghai	270
Beijing	270
Chengdu	270
Xian	270
Guangzhou	270
SURVEY TOTAL	**1620**

3. SCANNING PROCESS

3.1 Physical Field Conditions

Scanning under field conditions presented challenges not found in a static laboratory setting. Each of the six locations varied widely in terms of the physical spaces provided for operations, the organizational support available, and the living conditions for visiting staff. However, specifications provided in advance to each local contract officer defined the minimum type and number of physical spaces necessary.

The critical location was the lab environment for the scanning itself, which required the following physical features:

- a minimum of 20 square meters of area, approximately square in shape;
- proximity to restrooms;
- even fluorescent lighting at a bright level;
- no exterior windows (or windows that could be shielded);
- air conditioning, heating or fans as required for comfort;
- no carpeting to impinge on equipment installation;
- minimum of 5 separately fused 110 V outlets for equipment;
- secure locks for use at the end of the day, or monitoring by security.
- -minimum of 3 broadband internet connections for data transmission.

All of these criteria were essential for smooth operation of the test equipment. For example, direct sunlight interferes with the operation of the scanning laser, increasing scan "noise" and decreasing the amount of detail captured.

Participating sites were compensated financially for their collaboration in the project, and recognized in public communications for their supportive role.

3.2 Field Staff

The traveling survey team consisted of three trained anthropometrists and one professional photographer. The team spent a total of eight months traveling with their equipment to the different locations, reaching the sites by air travel where possible, but also traveling by land in a rented truck over gravel roads. The Cyberware 3030 Color 3D Scanner traveling with them had been selected in part for its mechanical durability and ease of set-up, and performed without problems during the entire period.

At each location, approximately ten local staff members were hired to assist the visiting team, as the three experts alone were not sufficient to process the three to four hundred subjects passing through each location. Local staff members were recruited in advance of the arrival of the team by the local liaison officer working with the partnering organization at the site.

Our initial request for 270 subjects was surpassed at every location, and the survey was able to scan 15% more subjects than anticipated.

3.2 Subject Scanning

3.2.1 Recruiting

Recruiting of the subjects was done in advance by the local liaison officer of the host organization following the sampling matrix specification provided by the Hong Kong team.. Each recruit was given an appointment time, and told to expect the entire process to take 30 minutes. In expectation of "no shows" among the recruits, each site scheduled more than 270 subjects to ensure the full number were met however the number of "no shows" was consistently lower than expected.

3.2.2 Video introduction

At Station 1, "Video Introduction," subjects were invited to sit in groups of 5- 10 in a quiet area to watch a short 4 minute Mandarin-language video program describing the project. Made in Hong Kong by project staff, the video provided background about the significance of the goals of the project and its methodology. It also provided general instructions about how to help achieve a good scanning result.

3.2.3 Survey

At Station 2, subjects filled in a questionnaire to document basic information about age, gender, family background, the location where they grew up, and so forth. Each subject was assigned a scan reference number. Subjects carried the survey questionnaire with them throughout the rest of the scanning process, to allow further information to be added at each station. Scan subjects also signed a release form for the use of their demographic, digital and photographic data.

3.2.4 Reference numbering

The unique reference number assigned to each subject was noted on the questionnaire and also printed onto an adhesive label to be fastened to the subject's upper left shoulder. In that position, the number could be seen in photographs to serve as a reference double check if required later. Reference numbers were used to avoid the use of names, which would have violated ethical confidentiality. Subject names were not recorded.

3.2.5 Photography

At Station 3, "Photography," subjects posed for high-resolution photographs of a front view and side profile, taken against a neutral gray backdrop. For these photos, the people were asked to relax their faces, avoiding posing or smiling. The photographs served two purposes. They provided a visual reference for comparison against the 3D scans in the event of confusion in the numerical reference system. In addition, they serve as an archived resource that may find future use in emerging new areas of research, such as photogrammetric 3D modeling and facial recognition technology research.

3.2.6 Traditional anthropometric measurements

At Station 4, traditional anthropometric measurements were recorded for each subject. Height and weight were measured with a medical quality scale brought by the traveling team, and calibrated at each site to ensure accuracy and consistency. Measurements of the length and width of the head were taken using an anthropometer (a specialized form of caliper), and the circumference of the head measured using a tape measure.

Despite the fact that SizeChina was planned as a 3D scanning survey, traditional measurements remained important. Traditional measurements served as a double check on the accuracy of the scan information, and also provided a benchmark for compensatory calculation of hair thickness effects as recorded by the laser. They also served an important role as a sorting tool used during the later data processing stage of the project. Entered into cross-referenced spreadsheets, traditional univariate measurements lend themselves to the easy comparison and sorting of different groups.

The specifics of all of head measurements followed the guidelines of ISO 7250, "Basic human body dimensions for technological design".[7] Where the other stations employed local recruits trained to follow the project procedure, this station was manned at all times by one of the project's own anthropologists. The measurements obtained were manually recorded on each subject's questionnaire.

3.2.7 Landmarking

A second anthropometric expert from the core team was located at Station 5, "Landmarking." Here, physical palpation of the subject's head was used to locate bony landmarks on the skull below. Fifteen standard facial landmarks were referenced in the survey, eleven of which required palpation to be located. Palpated landmarks were marked on the skin, using an eyebrow pencil to make a small 2 mm dot. These small black dots were then covered by 5 mm adhesive backed red dot purchased at a stationary store. The larger red dot is used to enhance the visual contrast between the skin and the landmark location on the 3D scan file. The red dot also makes it easier for the CAD operator to identify landmark locations during scan processing as it sits above the surface of the skin.

Each anthropometric study uses different land marks as no standard exists that defines a consistent set of parameters. Our specific selections of landmarks were recommended for use in SizeChina by an anthropometric consultant, who did an analysis of the project requirements to identify landmarks that offered a high level of descriptive accuracy in combination with computing economy.

The landmarks used were:
— Chin: the most protruding forward point on the bottom edge of the lower jawbone;
— Ectocanthus: the outside corner of the right eye formed by the meeting of the upper and lower eyelids (this point did not need to be marked with eyebrow pencil as it was self-evident in the scans);
— Frontotemporale, right and left: the point of deepest indentation of the temporal crest of the frontal bone above the brow-ridges;
— Glabella: the anterior point on the frontal bone, midway between the bony brow-ridges;
— Infraorbitale, right and left: the lowest point on the anterior border of the bony eye socket;
— Pronasale: the point of the anterior projection of the tip of the nose (self-evident and unmarked);
— Sellion: the point of the deepest depression of the nasal bones at the top of the nose;
— Top of head: the highest point on the head when the head is held with the Frankfort plane horizontal (self-evident and unmarked);
— Tragion, right and left: the superior point on the juncture of the cartilaginous flap (tragus) of the ear with the head;
— Zygofrontale, right and left: the lateral point of the frontal bone on its zygomatic process.

3.2.8 Wig cap

At Station 6, subjects put on a tight fitting nylon wig cap, taking care to tuck it all strands of hair under the edges of the cap, particularly around the ear. The wig cap served two purposes. By compressing the excess volume of fluffy hair styles, it better revealed the underlying shape of the head. The wig cap also reduced the reflective shine that is typical of black Chinese hair. Left uncovered, a shiny black surface would reflect the scanning laser, leaving holes in the 3D data.

3.2.9 Scanning

At Station 7, each subject was seated in a chair positioned inside the scanning set-up, and, at last, scanned. The team's third traveling anthropology expert was positioned at Station 7 to operate the scanner.

The scanner head array of the Cyberware 3030 Color 3D scanner is comprised of the laser itself, plus a beam splitter, mirrors, and a receiving camera. This entire scanner head assembly is mounted so that it can rotate about the head of the seated subject. As it moves, it captures one vertical contour at a time as a line of spatially defined points. When the full rotation has been completed, the full 3D volume of the head is defined as a " point cloud" of three-dimensional points in space.

During scanning, spatial information is fed directly into a computer for immediate display as an image on a video screen. The image is composed of the cloud of 3D points, each of which is defined by its individual X, Y, and Z coordinates. If the scan is successful, the displayed image will provide an accurate representation of the scanned subject with an estimated error of approximately plus–or-minus 1 mm per axis".[8]

Because the light moves very quickly, there is little effect from movement during the recording of any one vertical contour. However, it takes 17 seconds for the scanner to complete a full revolution around the head. During that time, head movement will cause improper integration between the vertical scans. Typical head movements include a sudden movement, or twitch; and a slow drifting movement. In all cases, individual vertical contours remain accurate, but movement during the scan will cause an incomplete integration between the vertical lines.

Such errors create a data gap or "closure gap" between the start and finish of the scan. This gap appears visually as an apparent space at the back of the head where the profiles do not line up. Visual assessment of closure gap is a quick and effective way to judge a scan's quality. Because the captured image is displayed immediately, the quality of the scan can be assessed while the subject is still seated. In the case of any evident movement or other errors, such as those caused by environmental noise, the subject can be scanned a second or even third time.

During the scanning process, 17% of first scans of adults were repeated after the first scan was rejected as unsuitable. A very few elderly people suffering from slight tremors or shaking proved unable to participate in the scanning part of the survey altogether.

In the separate survey of children, when children under the age of five were scanned, the rejection rate was close to 100%, because such young children were unable to sit still for the full 17 seconds it took to complete one rotation of the scanner. Further experiments on very young children were conducted using a different system, photogammetry, at the Hong Kong Polytechnic University but the slow speed of the software and the fragility of the physical system proved to be of limited effectiveness at this time.

Figure 2: 3D scan images of a subject in the 30-50 year old range.

3.2.10 Data check

After visual confirmation that the scanning was satisfactory, subjects proceeded to the last step, Station 8. Here, a locally-trained clerk collected questionnaire forms and wig caps from the subjects and confirmed that the forms were properly completed. Each participant then received a financial gratuity, as well as a souvenir printed copy of their personal 3D scan.

At a nearby grooming area, subjects removed all sticky labels, washed off the eyebrow pencil and said goodbye. The entire process from video to wash-up typically took about 30-40 minutes.

3.2.11 Data entry and backup

Managing the storage, archiving and transmission of the large amounts of data produced by a scanning survey collects required creative use of a variety of formats and media. Overall, the SizeChina survey generated a full terabyte of data including scans, photography and documentation. With individual scan files exceeding 20 MB in size, scan data could not be stored in the field laptops used to operate and monitor the scanner. External storage drives were utilized with DVD back-up copies made at each location at the end of each working day, to be shipped to Hong Kong via courier at the end of each location study. On two separate instances, the back-up copies proved invaluable when external hard-drives experienced equipment failure under field conditions, losing several days worth of data.

The handwritten survey questionnaire information was manually entered into computer spreadsheet software on site, and transmitted back to Hong Kong electronically via email. The original paper questionnaires and subject release forms were packed for shipping back to Hong Kong with the project equipment, where they were archived for future

4. DISCUSSION

During the eight month site survey process of the SizeChina project, a traveling team composed of three anthropometric experts plus a photographer traveled to six different sites on the mainland of China, bringing with them a 3D laser scanner and other equipment. Local institutional partners at each site provided the necessary physical facilities to house the scanning process, as well as recruiting approximately ten local staff at each location to help with management and data collection. At each site, 270 volunteer subjects were recruited to participate in the study, covering a full range of ages from 18 to 75+, in both sexes.

In setting up this study, SizeChina researchers were able to benefit from the prior existence of international standards for the collection of anthropometric data. Selection of the number and variety of subjects measured was planned in accordance with ISO 15535:2006, "General requirements for establishing anthropometric databases." Anatomical landmarks used in the data collection process matched the requirements of ISO 7250, "Basic body measurements for technological design."

At the same time as digitally scanning more than 2000 subjects, the team also collected traditional anthropometric data as well, to facilitate later double-checking and sorting of the digital data.
The creation of the SizeChina 3D database will allow researchers to discover if significant differences exist between North and South Chinese populations. The 3D data may also be used to discover the differences between Chinese and Western head and face shapes.

5. CONCLUSION

The survey collected the 3D data needed to determine the shape of the Chinese head. The high resolution 3D data collected for implementation into design practice allows for the creation of objects tailored to the Chinese head. The problems of low resolution full body scans as a basis for design practice have been overcome.

6. REFERENCES

[1] Roger Ball M., "SizeChina," www.sizechina.com (accessed 10/05, 2008).

[2] J. F. Annis, Anthropometric Sourcebook, Vol. Volume 1: Anthropometry for Designers (Houston, USA: NASA - Reference Publication 1024, 1978).

[3] J. A. Roebuck, E. Kromer and W. Thompson, Engineering Anthropometry Methods, 2nd ed. (New York: Wiley and Sons, 1975).

[4] Standards Administration of the Peoples Republic of China, GB10000-88: Human Dimensions of Chinese Adults. (in Chinese) (Beijing: Standard Press of China,[1993]).

[5] International Standards Organization, ISO 15535:2006 - General Requirements for Establishing Anthropometric Databases (Geneva: International Organization for Standardization, [2006]).

[6] C. Gordon and B. Bradtmiller, 1988 Anthropometric Survey of US Army Personnel: Methods and Summary Statistics (Natick, MA, USA: US Army Natick Research, Development and Engineering Center, [1989]).

[7] International Standards Organization, Basic Human Body Measurements for Technological Design (Geneva, Switzerland: International Organization for Standardization, [1996]).

[8] B. Bradtmiller, "Sizing Headforms: Design and Development" (Detroit, USA, 1996).